A Program of Economics Research on Improving Estimation of Benefits from Reduced Pollution

Prepared for the

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Executive Summary

While recent evidence from public opinion polls shows no significant decline in support for environmental protection programs on the part of the population, the disturbing economic problems of the late 1970's have led many people, both in and out of government, to ask whether in all cases the benefits of the programs designed and implemented over the past decade can be shown to justify the program costs. The resulting call for more comprehensive application of benefit-cost analysis has stimulated in turn renewed interest in the technique itself, its strengths and weaknesses; and a realization that our knowledge of the benefits of national environmental protection programs is largely inadequate to the projected task.

In evaluating environmental protection programs or regulations, benefits are the damages prevented by the program or regulation ("policy" for short). That is, program benefits equal damages suffered in the absence of the policy less damages suffered with the policy in place. In some cases, benefits can be measured retrospectively, as the actual results of existing policies. For policies not yet fully in place, however, benefits must be estimated prospectively; that is, they must be predicted.

Even in traditional applications to the evaluation of public works projects, benefit-cost analysis has had trouble with benefits when these accrue via the production of goods or services for which there are no markets -- whether the lack of markets is a matter of physical necessity (as for the creation of scenic vistas) or of custom (as for water-based recreation). These difficulties are exacerbated by some of the important characteristics of the damages attributable to environmental pollution, and hence of the benefits that result from controlling that pollution. In particular, there may be large geographic areas and populations suffering the actual or prospective damages; these damages may involve very subtle health effects or changes in ecological systems; and in many instances the time scale for future damages is also very long, so that future generations are involved.

In the light of increasing official interest in using benefit-cost analysis to evaluate EPA's environmental programs and specific regulations, a committee of economists* was convened at Resources for the Future in December 1980 for the purpose of considering what we know about pollution control benefit estimation, how much confidence we can place in existing estimates, what methodological questions most urgently need attention, and what major data gaps demand filling. The attached report contains the committee's judgement on those issues.

Programs and Benefits: A System Overview

The EPA programs for which benefit estimates are desired are diverse. The major ones are:

- air quality
- water quality
- solid wastes

* See Appendix A for committee membership and participation details.

- drinking water
- noise
- radiation
- toxic substances.

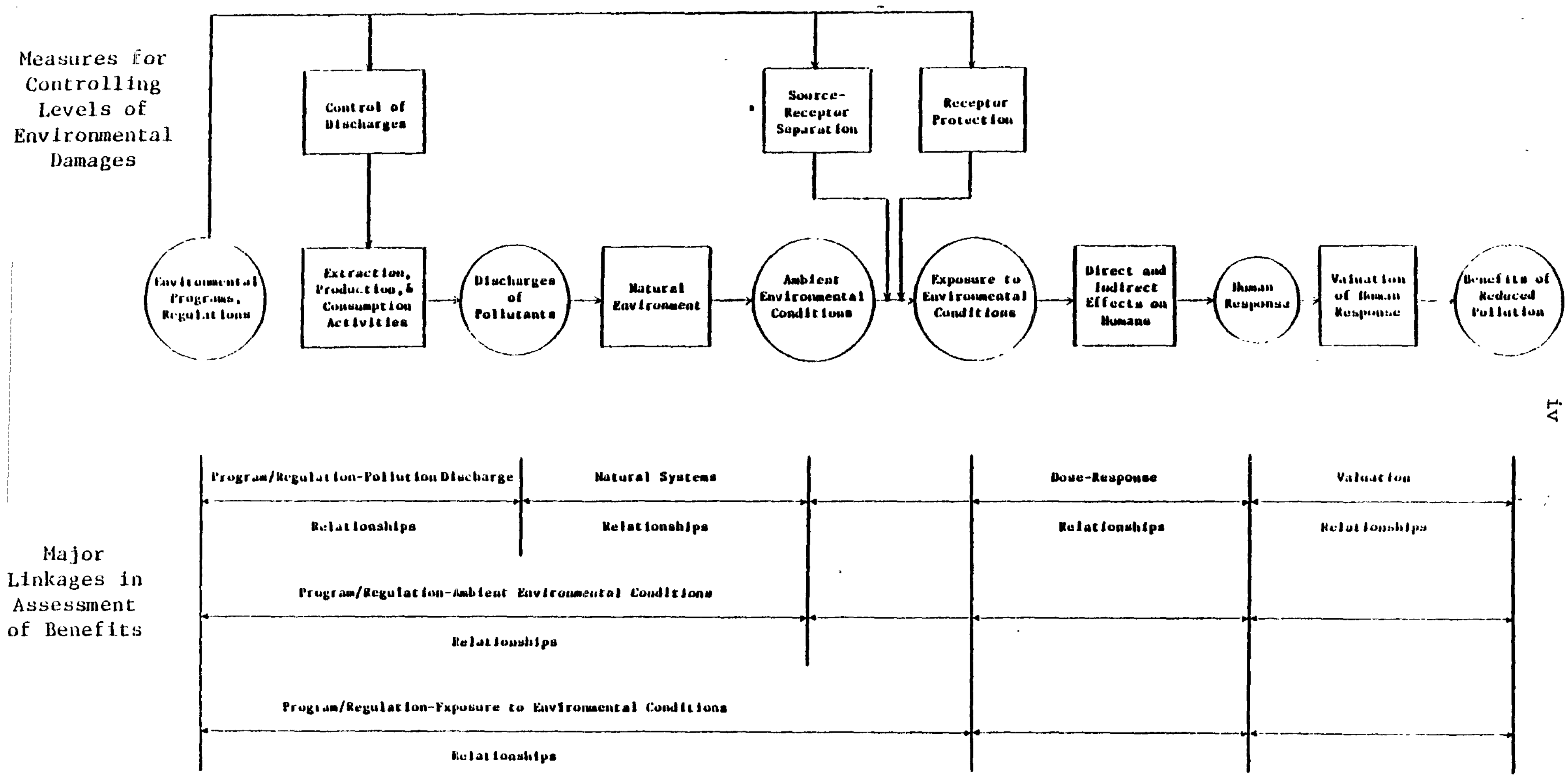
The elements of the system by which these programs produce benefits are, however, shared. These elements include:

- Measures for controlling levels of damage:
  - control of sources of pollution discharge or release
  - separation of pollution sources from receptors of damage
  - protection of receptors.
- Linkages from man's production and consumption activities to the experience of damages
  - effects of program or regulation on discharge or release of pollutants
  - transportation, dilution, transformation of pollutants by natural systems producing ambient environmental conditions
  - human responses to changes in ambient environmental conditions
  - valuation of human responses.
- Categories of damages (hence of benefits)
  - human health
  - recreation and amenity
  - marketed goods
  - knowledge of desirable (or undersirable) public actions to preserve or enhance the environment
  - anxiety and loss of future options.

One view of the relationship among these elements is shown schematically in figure 1.

Economics has its most obvious role in the valuation element of this system, but there are other elements of the study to which it can also contribute -- for example, in understanding human response to

Figure 1. A Schematic View of the System Involved in Producing Benefits from Programs and Regulations Intended to Reduce Pollution



changes in ambient environmental conditions, as in recreation, and the econometric-epidemiological approach to human health responses. In addition, the modeling of the natural system linkage, in order to capture the effect of programs and regulations on ambient environmental conditions, can best be undertaken in an interdisciplinary team setting because the appropriate level of detail and resolution in such modeling will depend on the techniques chosen for estimating human responses and for adding up the values of those responses to arrive at national benefit totals.

Special Problems in National Benefits Estimation

One especially vexing and sensitive problem in benefit estimation is the valuation of human health effects, whether these appear as increased days of sickness (morbidity) or in increased death rates (mortality). Earlier methods of valuing reductions in death rates, which were based on productivity measures for individuals of various ages and occupations, are being replaced by methods based on reductions in statistical risk to anonymous lives, with values being inferred from "risk premiums" found in wage differentials voluntarily accepted in occupational choices, or analogous risks "prices" found in other private decisions. There remain substantial questions, however, such as the acceptability. of extrapolation from voluntary private risks to involuntary public ones, and from specific groups of self-selected workers to the population at large.

Other special problems include:

- Valuation of amenity effects and of the knowledge that environmental quality is being maintained or improved. These categories of benefits are very difficult to approach via traditional methods, especially since the "knowledge" benefits and some general amenity improvements do not involve overt, measurable consumer behavior.

- Use of residential property value differentials as summary measures of a number of locally experienced pollution reduction benefits. This source of information is convenient, but it remains open to question just what effects it can be anticipated are capitalized in housing prices.

- The matter of adding up is, in fact, an especially tricky part of the process of national benefit estimation, for in some categories of damages the most natural units of observation and measurement do not lend themselves easily to subsequent addition of effects from a geographically comprehensive program. This is true, for example, of water-based recreation, where the site (such as lake, pond, or river stretch) is a traditional unit of observation. It is, however, difficult to define "site" in such a way as to allow division of all water bodies in the nation into appropriate units; and, in a setting of a national program of pollution control, measurements based on actual or prospective changes in quality at one site may be misleading guides because of widespread consumer shifting in site use.

EPA/ORD Program

The program of benefit estimation maintained over the past several years by EPA/ORD has made significant headway against some of these and other problems. For example: in the matter of valuing amenity and knowledge benefits, the program has supported research into the development of highly structured survey questionnaire techniques designed to avoid such anticipated pitfalls as the incentive for respondents to misrepresent their willingness to pay for program results (their anticipated benefits) and the lack of incentive for respondents to make an effort to think carefully about the questions. These techniques, in the form called "bidding games", have been applied to the valuation of visibility protection, both in such special settings as the Grand Canyon and in ordinary neighborhoods. In the latter case, it was possible to cross check the estimates of benefits against a property value measure,and the results showed an encouraging correspondence. Another survey technique, referred to as the "anchored estimate", has been experimentally applied to the estimation of the benefits people accrue because of their knowledge that the nation is acting to achieve comprehensive and ambitious water quality improvement.

Other advances have been made in the application of econometric-epidemiological methods to the determination of the human health effects of air pollution control and of drinking water quality improvement, and in the measurement of agricultural damage from air pollution.

A Research Agenda for Continued Progress

The committee's recommendations for a research program designed to improve our ability to assess the national benefits of EPA's programs and regulations may conveniently be summarized in three categories:

- development of methods and further benefit assessments
- data needs
- reduction of overall system uncertainties in national benefit estimates

Development of Methods and Further Benefit Assessments

The largest number of committee recommendations for further research involve application or refinement of promising, existing methods for benefit estimation. Prominent among these methods and applications:

- further work using econometric-epidemiological methods and aimed at estimating human response to varying doses of environmental contamination.
- use of risk premiums implicit in differential wage rates, property values, and other market prices as bases for valuing morbidity and mortality risks.

- comparison among the several available survey techniques for assessing willingness to pay for environmental quality improvements.

- application of survey techniques to such hard-to-approach categories of benefits as visibility improvement (or maintenance), knowledge of existence of clean environments, desire to maintain future environmental options, and reduction of anxiety about uncertain threats to health and well-being.

- investigation of data on membership in and contributions to environmental public interest groups as one possible basis for estimating amenity, existence and option value, and anxiety-reduction benefits.

- estimation of agricultural damages due to pollution using farm-level cost functions as these are affected by ambient pollution levels.

The committee also saw opportunities for the development of valuable new tools and suggested several initial steps to this end, including:

- a pilot study of the possibility of estimating the human health effects associated with ambient pollution from those resulting from exposure to contaminants in the work place.

- a pilot project on methods for estimating the economic value of damage to materials from environmental pollution.

- exploration of several alternative routes to valuing reductions in risk and in anxiety about risky situations. These would include the use of natural hazard analogs (such as floods and tornadoes), the extrapolation from other inherently risky social problems such as crime, and the study of legislative reaction to extreme events such as spills of contaminants or discoveries of hazardous materials dump sites.

Data Needs

Three major data needs were identified and recommendations are made concerning eventual improvement in the situation:

- health effects data at the level of individuals for whom we also have information on personal habits and exposure to pollutants (at work and at home, as well as in the ambient environment). This extremely important gap in available data can only be filled by a serious effort involving at least a cross section study of about 10,000 individuals. More desirable would be a panel study involving continuing study of 5,000 to 10,000 individuals over as long as 20 years.

- data on participation in water related recreation activities from enough individuals across the nation to allow estimation of participation prediction equations in which available water quality is one of the independent variables. Meeting this need will require a survey planned and executed along the lines of the U.S. Fish and Wildlife Services quinquennial survey of hunters and fishermen, but with questions concentrating on such activities as boating, swimming, and picnicking and hiking near water.

- data on the deterioration of materials <u>in use</u> due to ambient pollution. These data would have to distinguish damage according to its economic relevance (as in shortening the physical life of a product as opposed to reducing its aesthetic appeal). The committee was not ready to suggest how this should be accomplished and recommended pilot survey projects of materials damage in several economic sectors as ways to develop and test techniques.

<u>Reduction of Overall System Uncertainties in National Benefit Estimates</u>

It is not only the obviously economic parts of the benefit estimation system that contain uncertainties and thus detract from the usefulness of national benefit estimates. It is also true that:

- We are often very uncertain about how a program or regulation will change discharges of pollutants or releases of contaminants to the environment. (An area in which this is especially troublesome is the regulation of hazardous substances under TSCA and RCRA.)

- Our knowledge of how natural systems transport, dilute, and transform contaminants in producing ambient environmental conditions is often either inadequate or contained in models of such space and time detail as to render it practically unavailable for comprehensive national benefit estimation.

- The economic methods, though sound in themselves, may not be readily adapted to aggregation over the entire nation.

Accordingly, the committee recommended a pilot project on comprehensive analysis of uncertainties in national benefit estimates. This project would have as its objective a preliminary indication of which parts of the overall benefits system promise the best return to further research investment, where return is defined as reduction in uncertainty about benefits per dollar of research money spent.

Budget Implications

The budget implications of undertaking the research program outlined briefly above and described in more detail in the attached report are summarized in the table below. We have assumed that all except the continuing panel study for health and exposure data will be done over three years.

Estimated Budgets for Research on Developing National Benefit Estimates of Reduced Pollution

(1980 Dollars)

	With Single Cross-Section Health Effects Data Effort ($ million)	With Continuing Panel Health Effects Data Effort ($ million)
Methodology and Estimation[a]	$ 8.50	$ 8.50
Conferences	.18	.18
Meetings of Committee	.04	.04
Contingencies	.28	.28
Subtotal	9.00	9.00
Health Data	7.00	80
Recreation Data	1.80	1.80
Materials Data	1.00	1.00
TOTAL (over three years)	$18.80	$91.80
Per Year	$ 6.27 (For first 3 years)	$ 8.90[c]

Notes: a/ Includes pilot project on comprehensive analysis of uncertainties.

b/ 10,000 subjects @ $500 per year over twenty years with sufficient mortality to reduce undiscounted total costs to $80,000,000.

c/ Includes $5,000,000 per year for health data study.

I. Introduction to Benefit-Cost Analysis

In the 1960s, the people of the United States became increasingly aware that the fruits of economic development were infected by the rot of environmental deterioration. Late in the decade and early in the 1970s, concern grew to such an extent that a number of laws were passed by the Congress aimed at not only stemming the deterioration of the environment but improving it as well. As the nation moves into the 1980s, environmental concerns are still strongly alive, but other major national difficulties are also pressing. The economy is weak, inflation is high, and there appears to be no immediate hope for improvement. In this adverse economic atmosphere, there is heightened interest in the question of whether the costly environmental regulations that have been put in place are, in fact, worthwhile. To try to shed some light on this question, appeal is often made to an economic evaluation method called benefit-cost analysis.

Benefit-cost analysis was developed initially to evaluate water resources investments by the federal water agencies in the United States, principally the United States Bureau of Reclamation (now called the Water and Power Resources Services) and the United States Corps of Engineers. The general objective of the method in this application was to provide a useful picture of the costs and gains associated with investments in water development projects. The intellectual "father" of benefit-cost analysis was the nineteenth centry Frenchman, Jules Dupuit, who in 1844 wrote an often cited study, "On the Measure of the Utility of Public Works." In this remarkable article, several concepts were developed which are still central to the technique.

In the United States, early contributions to development of benefit-cost analysis did not come from the academic or research communities, but rather from government agencies. Water resources development officials and agencies in this country have from the very beginning of the nation been aware of the need for economic evaluation of public works projects. In 1808, Albert Gallatin, President Jefferson's Secretary of the Treasury, produced a report on transportation programs for the new nation in which he stressed the need for comparing,the benefits with the costs of proposed navigation improvements. Later the Federal Reclamation Act of 1902, which created the Bureau of Reclamation and was aimed at opening western lands to irrigation, required economic analysis of projects. The Flood Control Act of 1936 proposed a feasibility test for flood control projects which requires that the benefits "to whomsoever they accrue" must exceed costs.

In 1946, the Federal Interagency River Basin Committee appointed a subcommittee on benefits and costs to coordinate the practices of federal agencies in making benefit-cost analyses. In 1950, the subcommittee issued a landmark report entitled "Proposed Practices for Economic Analysis of River Basin Projects." This document was fondly known by a generation of water project analysts as the "Green Book." While never fully accepted, either by the parent committee or the pertinent federal agencies, this report was remarkably sophisticated in its use of economic analysis and laid an intellectual foundation for research and debate in the water resources area which made it unique among other major reports in the realm of public expenditures. It also provided general guidance for the routine development of benefit-cost analysis of water projects which persists until now, even though a successor report does presently exist which is more adapted to the conditions of the present day.

Following the "Green Book" came some outstanding publications from the research and academic communities. Otto Eckstein's Water Resources Development: The Economics of Project Evaluation (Harvard University Press), which appeared in 1958, is particularly useful for its careful review and critique of federal agency practice with respect to benefit-cost analysis. A clear exposition of principles together with applications to several important cases was prepared by Jack Hirshleifer, James DeHaven, and Jerome W. Milliman in Water Supply: Economics; Technology, and Policy (University of Chicago Press, 1960). A later study which was especially notable for its deep probing into applications of systems analysis and computer technology within the framework of benefit-cost analysis was produced by a group of economists, engineers, and hydrologists at Harvard and published under the title Design of Water Resources Systems in 1962 (Harvard University Press). The intervening years have seen considerable further work on the technique and a gradual expansion of it to areas outside the water resources field. A more recent book which looks at some applications to public works other than water-related ones, but which is in the mainline of the traditional benefit-cost analysis, is Ezra Mishan, Cost-Benefit Analysis (Praeger Publishers, 1976). In addition to these, there is also a rich literature on the subject contained in professional journals.

The most striking development in benefit-cost analysis in recent years has been its application to the economic and environmental consequences of new technologies and scientific and regulatory programs. For example, the Atomic Energy Commission used the technique to evaluate the fast breeder reactor program (U.S. Atomic Energy Commission, Updated (1970) Cost-Benefit Analysis of the U.S. Breeder Reactor Program, Washington, D.C., January 1972). Other studies have been or are being conducted in the areas of water quality analysis, emissions from stationary and mobile air pollution sources, and regulation of toxic substances.

Even while the technique was limited largely to the relatively straightforward problem of evaluating public works, there was much debate among economists about appropriate underlying concepts and methods of making quantitative estimates of benefits and costs--especially of benefits. Some of the discussion addressed primarily technical issues, for example, how best to estimate the demand functions for various outputs of projects where the outputs were not bought and sold in markets. Others were more clearly value and equity issues, for example, whether the distribution of benefits and costs among individuals or regions needed to be accounted for or whether it was proper to consider only the sums over all affected parties. Another central issue was what the proper weighting of benefits and costs occurring at different points in time was to be. This is known as the "discounting" issue: whether the further in the future benefits or costs accrue, the less heavily they should be weighted in making benefit-cost comparisons. Such "discounting" is consistent with private behavior in both consumption and savings (investment), but is considered by a significant minority to be inappropriate to public decisions involving long time periods and widely distributed benefits or costs.

Application of benefit-cost analysis to issues of air pollution, water pollution, radiation, storage of atomic wastes, and the regulation of toxic substances in the various environmental media, further aggravates both the conceptual and quantification problems which existed in water resource applications. There are several reasons for this.

First, while the evaluation of water resource projects often involves benefits attributable to public goods -- that is, goods or services supplied, if at all, in equal amount to a group of consumers none of whom can be excluded from enjoying them (for example, flood control supplied to a downstream city by an upstream dam), the bulk of outputs from such projects -- irrigation water, navigation enhancement, flood control, and municipal and industrial water supplies -- can usually be reasonably well-evaluated on the basis of some type of market price information. This is because private developments often produce similar or closely related outputs. Environmental quality applications primarily involve public goods where useful information from existing markets is difficult, if not impossible, to establish.

Second, such matters as nuclear radiation and toxic materials, and even some aspects of air and water pollution, relate to exposure of the whole population, or large subpopulations, to very subtle influences of which individuals may be entirely unaware. It is difficult to know what normative value people's preferences have under these circumstances, and clever methods of quantifying benefits (the avoidance of damages) have to be evolved, not to mention justified.

Third, the distributional issues involved in these applications concern not only monetary benefits and costs, but also the distribution of actual physical hazard. For example, residents of an industrial city may suffer ill health resulting from pollution associated with the production of goods consumed in another locality. While it is not out of the question that monetary equivalents to these risks could be developed, the ethical issues involved appear to be deeper than just the associated economic returns. This is especially so if compensation is not actually paid to damaged parties, as in practice it is usually not.

Fourth, in some cases, the effects of a policy decision could extend to hundreds of thousands of years and to many, many human generations. Such problems raise in especially stark terms the questions of if and how the rights and preferences of future generations should be represented in decision processes today. Realistically, the preferences of the existing generation must govern, for example, in deciding how to dispose of nuclear waste materials. The question is whether the simple direct desires of existing persons alone are to rule or whether justice demands that the present generation adopt some more discriminating ethical rule or rules of a constitutional nature in considering issues affecting future generations.

Applications of benefit-cost analysis to the nation's environmental programs bristle with ethical, value, and quantification issues; issues that are far from settled and will require substantial efforts in research and data collection before significant further progress can be made in evaluation. The purpose of this document is to provide the U.S. Environmental Protection Agency with an agenda for economics research on improving the estimates of benefits from reduced pollution. This research agenda is based on the concensus of an Ad Hoc Committee comprised of leading academic researchers and practitioners in the field of environmental quality benefits assessment (Appendix A). The Committee met in Washington, D.C. on December 29th and 30th, 1980 to discuss research needs and priorities. Those who were not able to attend the meeting were invited to comment on the draft material provided, but this final version has not been reviewed by the Committee.

This research-needs statement is divided into six major sections, this Introduction being the first. In the next section, the relationships between EPA's various environmental programs and improvements in environmental quality are developed, including some of the cross-media linkages where regulations in one program can affect the extent of environmental damages in a different environmental medium. This section is primarily conceptual. Its intent is twofold: first, to provide an overview of the essential elements of the environmental benefits estimation problem using the environmental policy as the point of reference for comparing costs and benefits; and second, to indicate where the economics research addressed in the following three sections of this statement contributes to the overall benefits assessment problem faced by EPA.

The third, fourth, and fifth major sections of this document deal directly with economic issues and research. The third section addresses problems of assigning economic values to improved environmental quality. The fourth is a brief statement of the state-of-the-art in assessing the economic benefits associated with improvements in environmental quality, concentrating on research sponsored by EPA's Office of Research and Development. The fifth major section focuses on economics research and data needs--the information and data gaps--on promising approaches to closing some of these information gaps, and on research strategies for the next stage of the research. The sixth and final section of the report provides an estimated budget for the research proposed in the fifth section.

Some of the exposition presupposes a basic amount of knowledge of consumer demand theory. For those interested readers who have not been exposed to demand concepts, or who wish to review them, a brief appendix is attached setting out the main ideas (Appendix B).

II. Assessing the Benefits of the EPA's Environmental Programs and Regulations: An Overview

To evaluate the benefits of an environmental program or regulation, a comparison must be made between estimates of the environmental damages that would occur in the absence of the program or regulation and those remaining after the program or regulation has been fully implemented. The difference between these two damage levels, generally referred to as the damages avoided, represents the benefits of the program. This sounds straightforward, but there is more to it than meets the eye. In making this comparison, it is first necessary, at least in principle, to delineate the pathways of all potential impacts of the program or regulation on people's uses of the environment both now and in the future. In some cases, such as with acid rains, this will involve specifying linkages between environmental media. After these pathways have been identified, it is then necessary to assess the extent of the various impacts and to value them in monetary terms. Finally, it is necessary to aggregate the individual benefits (damages avoided) across all benefit categories and across all activities (e.g., households, individuals) in the geographic area of interest, such as the region of the country or the nation as a whole.

The Benefit Estimation System

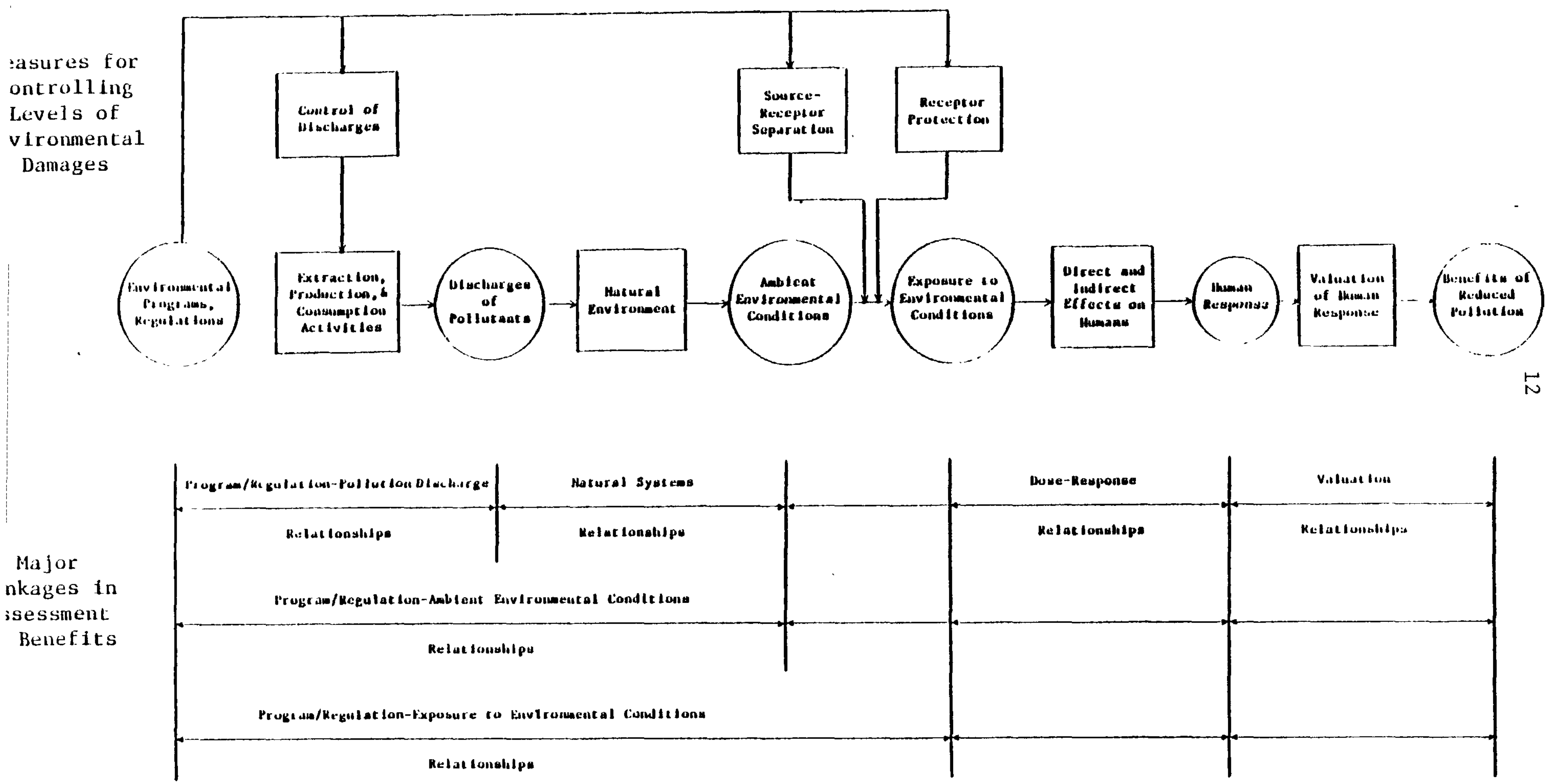
The research agenda presented in section V of this statement is designed to support benefit assessments of specific environmental regulations as well as EPA's seven major environmental management programs: air quality, water quality, solid wastes, drinking water, noise, radiation, and toxic substances. All of these regulations and programs may be assumed to have,at least as one objective, the goal of decreasing damages to people, and more broadly to the natural environment, of discharges or releases of unwanted waste materials or energy from human production and consumption activities. The means used to control the level of damages are almost always one or another combination of three basic measures: (1) source control (e.g., wastewater treatment or hazardous waste landfill construction rules), (2) receptor protection (e.g., water treatment, sound barriers), and (3) separation of source and receptor (e.g., land use restrictions). Thus, analysis of the costs and benefits of any one program or regulation involves consideration of an entire "system", and a rather complex one at that, in which people in their production and consumption capacities and the natural processes of the environment play significant roles. To compare in a consistent and meaningful manner estimates of the costs and benefits accruing throughout this "system", it is necessary to select a reference point for the analysis. For our purposes, the appropriate point of reference is the environmental program or regulation. Thus the "benefit function" begins at the policy (a useful shorthand for "program or regulation") itself.

The relationship between the environmental program or regulation and the value (benefits) of environmental services, in general, consists of four major linkages: (1) the relationship between the regulation or program and discharges of pollutants and contaminants to the environment; (2) the relationship between discharges of pollutants and contaminants and ambient environmental conditions (the natural systems relationships); (3) the relationship between ambient environmental conditions and the direct and indirect effects on people (the "dose-response" relationships); and (4) the relationship between direct and indirect effects on people and the monetary value of these effects.

It is also useful to divide the types of damage that may be suffered because of environmental pollution into five categories: (1) human health effects (increases in the incidence of mortality or morbidity); (2) recreation and amenity value (changes in the pattern or quality of recreation experiences or in the quality of the sights, sounds, or smells of everyday life); (3) existence values (values deriving not from the direct use of environmental amenities but from the intrinsic value people place on the mere existence of certain levels of such amenities -- or said differently, values deriving from knowledge that certain levels of amenity are to be sought or maintained); (4) effects on marketed goods (e.g., corrosion and clogging of water-using machinery or damages to materials and crops due to air pollution); (5) contingency values (values deriving from situations of environmental risk, where the effect, whether short or long run, is uncertain, and therefore anxiety may be suffered or future options lost).

The relations among the elements of the benefit analysis system are shown schematically in figure 1. Very little more will be said about the varieties of control measures; it is assumed in most of the discussion that source control is involved. We do, however, consider explicitly benefits accruing from drinking water

Figure 1. A Schematic View of the System Involved in Producing Benefits from Programs and Regulations Intended to Reduce Pollution



protection, where receptor protection is a key regulatory element, and the methods and data methodological issues discussed are broadly applicable to any of the three approaches or to a combination of them.

It does seem worthwhile to say more about the linkages, for these are often neglected in discussions of benefit estimation and pose special problems for the analyst or team of analysts. In general, the estimation of the benefits of a proposed or existing program or regulation would require analysis, of or at least assumptions about, each linkage. (Though in some cases it will be possible to combine or skip links.)

The first linkage would have to be understood in order to predict how implementation of the program or regulation would affect waste discharges or contaminant releases to the environment. This may involve translating generally stated legislative goals into quantitative effects, or allowing for exceptions and exemptions in the application of quite detailed regulations. It may further involve state-by-state differences in strategy or tactics,and even the making of guesses about how reporting requirements will be used to anticipate and avoid problems. In short, it is a difficult linkage to capture, though vital to the estimation of benefits.

The second linkage -- the natural systems relationships -- is used to predict the states of the ambient environment resulting from levels of waste discharges. There are two basic approaches to developing these relationships -- mass and energy balances, and statistical regression. Each has its advantages and disadvantages. Models in the first category -- e.g., air quality dispersion models, chemical reaction models, water quality models, aquatic and terrestrial ecosystem models -- are most highly developed in their transport dimensions, with the notable exception of toxic materials. Models which include complex chemical and biological reactions and interactions are still in their developmental stages although substantial progress has been made in the last decade.

In cases where intermedia linkages are involved, they are included as part of the analysis of natural systems relationships. Waste discharges to one environmental medium can result in damages to another environmental medium. In estimating benefits, all the relevant cross-media effects should be identified and reflected in the analysis. The most notable current example is acid rains which originate as discharges to the atmosphere of sulfur and nitrogen oxides from combustion processes and ultimately damage soils, plants, and aquatic ecosystems, particularly fisheries. Other cross-media examples include discharges to the atmosphere of toxic materials from coal combustion (e.g., heavy metals and other trace elements) which are subsequently deposited on lands and watersheds and which eventually find their way to surface and groundwater supplies, and hazardous solid wastes that leach from their disposal sites to the surrounding soils and surface and groundwater supplies.

Development of natural systems models and relationships is the domain of the natural sciences -- meteorology, hydrology, hydrodynamics, limnology, chemistry, biology, and ecology; applied physics and mathematics; and engineering -- primarily civil, sanitary, and water resources. If estimates of the national benefits of environmental programs and regulations are to be improved, more research will be needed here.

The third major linkage -- the dose-response relationships -- is used to relate ambient environmental conditions to the five broad categories of damages. Much work remains to be done on the ambient environment-user response relationships if truly significant progress is to be made in improving estimates of the benefit of environmental policies. This area is partly the domain of economists and partly the domain of others -- e.g., epidemiologists, toxicologists, physiologists, chemists, agronomists and plant physiologists, materials engineers, and fish and wildlife specialists. Research by economists is particularly needed in those areas where others have, not developed relationships useful in benefit estimation. For example, more needs to be known about the human health impacts of environmental contaminants in the air we breathe, the water we drink, and in the food we eat. Epidemiologists, toxicologists, and health specialists have not given the human health impacts of environmental contamination the kind of attention that is required to develop useable damage functions. The linkage between levels of contaminants in the environment and health effects is hard to establish, especially the chronic as opposed to acute effects. Animal studies have well-known deficiencies, especially with respect to low levels of environmental pollution. Consequently, substantial information gaps remain which make it virtually impossible to assess the effects on human health of controlling waste discharges to the environment. Better data on the effects of long term exposure to environmental contaminants are badly needed. Economists have contributed much in the past to a better understanding of health related impacts, and can continue to contribute in the future.

The fouth and final linkage in estimating the benefits of environmental program -- the user response-valuation relationships -- is used to convert into monetary values the changes in anxiety levels, physical damages, aesthetics, recreation opportunities, and in human morbidity and mortality caused by environmental pollution and contamination. Research in this area falls squarely within the domain of economics. There are many techniques available here, ranging from the search for a relationship between characteristics of the ambient environment and information from functioning markets (such as differences in property values related to air pollution levels), to the use of survey techniques in which individuals are coaxed to reveal directly their willingness to pay to avoid specified damaging situations or to achieve desired environmental goals.

The distinctions among these four major linkages are important for two practical reasons: first, an estimate of the benefits of one of the Nation's environmental programs or regulations will have to reflect some or all of these linkages -- which ones depending on the specifics of the situation. Second, the mix of disciplines, the level of effort required to obtain a useful benefit estimate, and the value of and opportunities for further economics research vary depending on what must be included in the computation. The purposes of research and of developing better data sets are to improve estimates of the benefits. This can be achieved by reducing systematically the uncertainties in the four relationships discussed above. Uncertainties exist in all four relationships and these uncertainties are compounded in actual assessments of benefits. Placing the benefit estimation problem in a systems context can assist in identifying areas where research is needed and, further, in identifying areas where the greatest payoffs are likely to occur.

Special Considerations and Issues

It is worth emphasizing the generality of this systems view. It can be applied to any regulation or program now within EPA's purview and, indeed, to any EPA is ever likely to control. We purposely chose this framework for organizing the report because we felt that the obvious alternative -- an inventory of specific programs and regulations with attendant research needs -- would result in great problems of repetition and annoyance to the reader. Further, much of the research on the development of methods proposed in section V involves generic problems or techniques applicable across a wide range of programs and regulations. In many cases, therefore, economies of scale in research are anticipated.

We should also point out that benefit analysis may be performed either before (*ex ante*) or after (*ex post*) implementation of the policy and that the issues and problems involved vary depending on the perspective. For *ex ante* analysis, it is necessary to predict the states of the ambient environment with and without the policy. For *ex post* analysis, we know the actual state of the environment, but we must "predict" the state that would have occurred without the policy and determine what portion of the difference may actually be attributed to the policy. That is, we must do our best to make sure that the "prediction" really holds all factors other than the environmental policy constant.

Finally, before leaving this section, one more issue must be addressed: the special nature of the benefit aggregation problem. In past assessments of national benefits, the aggregation process has introduced as much uncertainty as has imperfect knowledge of the four major linkages discussed above. Most benefit studies have focused on a rather narrow set of benefit categories and on a specific geographic area, and when the time came to produce a national benefit estimate, heroic assumptions were made and the results of the more detailed studies were extrapolated far beyond what might be considered justified. Ways must be found to produce more realistic national benefit estimates from detailed case studies, and the benefit aggregation problem deserves special attention.

Continued research by economists on the third and fourth areas (linkages), and on problems of aggregation, promise to play an especially important role in achieving EPA's objective of obtaining better estimates of the benefits of its environmental programs and regulations.

III. Problems of Assigning Economic Values

Introduction

Once links have been established between proposed or established EPA programs and regulations and the associated direct and indirect effects on humans, then the central problem becomes one of measuring the economic demand for a cleaner environment. That is to say, what is the economic value to be attached to a given level of improvement, or to successively higher levels of improvements, in environmental quality? The methods used to make estimates of these values necessarily differ among the different types of effects associated with environmental quality deterioration. This is partly inherent in the different situations, for example, whether the effect is directly or indirectly on consumers, and partly a matter of the types of data it is practical to acquire. As further background for understanding and appreciating the research and data needs outlined in the fifth section of this report, we briefly review some central issues in the economic evaluation of three of the major routes by which environmental effects are felt: (1) human health, (2) recreation and amenities, and (3) marketed goods. For purposes of illustration, we rely heavily on the evaluation of damages associated with air pollution. No effort is made to be exhaustive, but rather the aim is to give the reader an idea of the kinds of problems encountered when one aspires to assign economic values to environmental effects. Some other methodological issues arise as we pursue discussion of the ongoing and projected future research programs in the following sections.

Valuing Risks to Human Life

Some studies of the health effects of air pollution suggest that it may cause acute and chronic disease (morbidity), which in turn may contribute to higher death rates (mortality). A central question, then, is what value to place on decreased mortality. How much would people be willing to pay for a reduction in their risk of earlier death,or how much would they have to be compensated to voluntarily accept an increase in this risk?

Economists in the past have attempted to value human life as the future earnings over an individual's lifetime (the valued used being the discounted present value of expected future earnings). This approach, however, is now no longer viewed as acceptable. In the first place, it assumes that the value of a life can, in fact, be measured in economic terms -- a point certainly open to debate. Second, it implies that the lives of children, housewives, retired, and other unemployed individuals are worth less than the lives of employed heads of households. Nearly everyone would find these implications ethically unacceptable.

Thomas Schelling was apparently the first economist seriously to suggest using observed occupational risk premiums to obtain estimates of required compensation for statistical risks to life, and hence to value anonymous, statistical lives. (T.C. Schelling, "The Life You Save May Be Your Own", in Problems in Public Expenditure Analysis, Samuel B. Chase, Jr., Ed. (Washington, D.C.; The Brookings Institution, 1968, pp. 177-213). The cost of risk idea is ethically more appealing than the attempt to value a particular human life. The effort here is to put a value on a small increase or decrease in the probability of death for anonymous, statistical persons. Implementation of this approach has usually involved a search for information about how much people have to be compensated to voluntarily accept a small increase in risk in occupations differing in riskiness -- say the risk of additional death per thousand persons. Thaler and Rosen in 1974, using wage differences between jobs varying in the level of job-associated risk of death, were the first to estimate explicitly the value of changes in safety. They observed that workers in high risk occupations receive higher wages and argued that a value of safety could be imputed by examing these risk-related wage differences. Other factors which influence wages were statistically held constant by use of regression analysis. Unfortunately, however, the Thaler and Rosen study dealt with a class of individuals who, because they are engaged in risky occupations, may be less averse to accepting risk than the rest of the population. Even so, the estimate they make suggested that a small reduction in risk over a large number of individuals which saves one on average life per year is worth between one quarter and one million (1978) dollars per year. This is far higher than the numbers obtained in lost earnings studies.

The Thaler and Rosen results as well as those developed in a number of other studies are discussed and summarized in Martin J. Bailey's recent monograph, Reducing Risks to Life: Measurement <u>of the Benefits</u> (Washington, D.C.; American Enterprise Institute, 1980). His summary tables (pp. 40, 42) and related text, in which all values are in 1978 dollars, show that estimates of the value of a statistical life saved vary from $170,000 to over $3,000,000. Clearly, the cost of risk is not precisely known, and perhaps will never be, since attitudes -- risk averseness -- presumably can vary over time, between groups, and even in different situations. But, at least we have a range of values with which to make order of magnitude estimates of the costs of environmental risks. Likely values lie between a quarter of a million and a million (1978) dollars per life.

There are some additional observations to be made about valuing mortality risk by a particular number derived from observed behavior of people faced with risks. First, no distinction is made with respect to age, sex, employment, or other personal characteristics. This seems ethically acceptable, but might well be the subject for debate and perhaps even further study. Second, the value obtained from existing studies does not vary with the degree of risk. While we might in general expect the value per life to change as the number of lives at risk changes, a constant value may be defensible in the case of air and water pollution because it appears that we are speaking about at most a small change in the general risk to health. However, for some other environmental problems, and for such social risk problems as large scale natural hazards, this may not be a realistic assumption.

Valuing Recreational and Amenity Losses: The Case of Visual Perception

Questions about the value of visibility impacts have become significant in air quality policy, especially as it applies to conditions in the mountain West. The question of how to value such effects is a very difficult one. In an urban area, one might consider using differences in housing property values as an indication of amenity values people attach to air clarity. But in scenic rural area, such as national parks, this is clearly not feasible. Thus it has been necessary to develop and use alternative methods.

Several such methods rely on questions posed to recreationists and others affected by visibility impacts. In general, respondents are confronted with images of possible changes in air quality, in the form of carefully prepared photographs, sometimes supplemented by verbal description. The respondents' valuations of those changes are then sought by one or another questioning method. Further, respondents are asked to reveal other pertinent personal characteristics.

One method of Probing for valuations, called the "bidding game"; engages the respondent in a sort of auction, asking: Would you be willing to pay (or to accept as compensation, depending on the structure of the example situation) x dollars for the change? What about x + y dollars? If not that much, how about x + 1/2 y dollars? And so on until a final bid is reached. Responses to these types of questions are used to estimate demand curves for cleaner air, taking into account income, age, and other socioeconomic characteristics of the respondents.

Another alternative, known as "rank ordering" involves similar visual plus additional information, including same measure of the cost or price of a visit. Individuals are asked to rank the alternatives from most preferred to least preferred. These rankings reveal trade-offs among visibility, other attributes of the site, and money costs. These trade-offs can then be used to estimate the benefits of visibility improvement.

The major concern in using survey techniques to construct demand curves is that the reply to questions may be biased either because the interviewee wishes to deceive or because of problems in the way questions are posed. Possible biases which could well exist in theory have been a major preoccupation of researchers pursuing the bidding game approach. The main types of bias which have been identified as possibilities are: (1) strategic bias, which means that the respondent may attempt to influence the outcome or result by not responding truthfully; (2) information bias, which is bias resulting from lack of complete information on the part of the respondent; (3) starting point bias, where the respondent may be influenced by the opening bid which is usually suggested by the interviewer; and (4) hypothetical "bias" or inaccuracy, which could result from inability to confront the respondent with an actual situation, for example, using a photograph rather than an actual scene.

To test for the presence and importance of bias and to assist in developing methods to control for it, a number of "experiments" using bidding games have been conducted. The experiments show that all forms of bias can exist. However, it appears that problems of strategic, information, and starting point bias are all surmountable with proper questionnaire design and statistical analysis. This suggests that well designed bidding games produce reasonably reliable information about the value of clean air from the perspective of visibility, at least for specific well defined vistas. The problem of aggregating such values to achieve a regional or national benefit for a visibility protection policy remains to be solved.

Valuing Market Losses: The Case of Agricultural Impacts

Agricultural production, even in the most advanced countries, is heavily influenced by factors that are beyond the producer's control. Despite a tremendous Increase in per unit agricultural yields during the past three decades, in part due to successful breeding of high yield and disease resistant varieties of plants, favorable weather conditions, increased use of fertilizer, insecticides, and modern farm machinery, total world food production has not kept up with world population growth. Further, within the more industrialized countries, yields appear no longer to be increasing. This may be partly because of man-induced environmental factors, possibly including lower air quality, at least in particular regions. Some efforts have been made in the past to calculate yield reductions in such regions and then these reductions have been multiplied by crop prices to estimate the value of lost production. This apparently straightforward procedure, is, however, too simplistic and may very well lead to deceptive results.

The reason for this is that some particularly high value agricultural crops, such as vegetables and fruits, tend to be concentrated in particular geographical regions due to specific climate requirements. Given the concentration of such production, and the known adverse effects of air pollution on vegetables and fruits, one might expect price fluctuations for such commodities in response to changes in air quality. Any reduction of yields due to air pollution may affect consumers and producers of those commodities differently. That is, if the quantity demanded is not very responsive to price for, say, celery, consumers would suffer a net loss, while producers in general will benefit from the increase in price of celery resulting from the reduction in supply. On the other hand, if the quantity demanded is responsive to price, the quantity reduction would result in both a loss of consumers surplus and a loss of producer profits. In this case, the benefit from reducing air pollution consists of both the gained consumers surplus and the increased profit to producers.

Where price effects of the kind described may be important, it is necessary to develop a method which can properly handle them in the process of analyzing economic losses in agriculture from air pollution.

This also illustrates the idea of "derived demand". The willingness to pay for air quality is not, in this case, because consumers value the air quality directly but because it is an input to the production of something they want.

Residential Property Values: A Summary Measure?

In an effort to obtain a summary measure of the value people place on cleaner air, economists have developed a method called the "property value method" for application in urban areas. (This is a specific application of the more general technique sometimes called hedonic price or demand analysis.) The idea is to assemble information on all the various characteristics which might determine house prices (location, lot size, number of rooms, school district, etc.), on the characteristics of the owners (chiefly income), and on pollution levels at the sites studied. Then, using statistical regression analysis, it is possible to make an estimate of that part of the difference in house prices which is _separately_ associated with differences in air quality at the different sites. Through a procedure, which is a bit intricate, and which we need not review here, these estimates can be used to estimate an aggregate "demand" for air quality in the city or metropolitan area being studied. The word demand is in quotation marks in the previous sentence because economic theorists have determined that only under a particular set of circumstances can that number be regarded as a valid and accurate estimate of the actual willingness to pay for an improvement in air quality. Nevertheless, the method has some very appealing qualities.

It is sometimes relatively inexpensive to undertake property value studies for the necessary data may already exist, and the collection of new data, which tends to be quite expensive, may thus be avoided.

If a property value benefit estimate can be made in a particular situation, it has the further advantage of providing a _summary_ measure of the value of air quality to people, subsuming,as it is normally assumed to, such sources of damage (benefit) as visibility, soiling and materials damage, and to the extent perceived, health effects. That is, it is possible to argue that all (or almost all) the effects of air pollution are reflected in differential property values,for it is through the purchase of particular pieces of property that consumers act to "buy" a particular level of air quality along with a bundle of other site characteristics.

IV. The EPA-ORD Benefits Estimation Program: Accomplishments and Ongoing Activities

The EPA program of studies on methods of benefits evaluation has already involved work on a number of categories of environmental benefits and has begun analysis of some of the types of problems outlined in the previous section. The benefits categories addressed include recreational, amenity existence values, health, and agriculture. Special studies undertaken as part of the research include a comparison of bidding games and property values in the Los Angeles region, applications of econometric methods to epidemiology, valuation of health risks, acid rain damage, and agricultural damage from air pollution. Selected results and ongoing activities in these areas are reviewed briefly below.

Recreational, Amenity, and Existence Values Benefits

Air Quality. One of the more significant studies in this area used a bidding game to examine the value people place on the visibility around Grand Canyon National Park. The game was designed to elicit both user value and existence value (the value people who do not use the park nevertheless place on the existence of clean air there) from the respondents. During the summer of 1980, people in Denver, Los Angeles, Albuquerque, and Chicago were shown photographs displaying different levels of air quality at the Canyon and were asked to say how much they would be willing to pay to maintain high visibility. The bid offered by a respondent to preserve or improve visibility was related to his or her income, education, and other personal characteristics, and these relationships could be quantified. After this was done, it was possible to estimate the benefits to residents of the whole Southwest region as well as the entire nation by applying statistical techniques to the results of the survey. The results indicated that for the Southwest Region (for residents of California, Colorado, Arizona, Utah, Nevada, and New Mexico) annual benefits from visibility protection at Grand Canyon National Park might amount to nearly nine hundred million dollars; and for the United States as a whole, the value might approach ten billion.

These results reveal that Americans place great value on the preservation of air quality in the Grand Canyon region and that this valuation is not localized in the Southwest, but probably extends to people all over the nation. Further, it was found that the existence value overwhelms a substantial user value for the National Parks in the region.

Because the Grand Canyon is the dominant feature in a region with many visitor attractions, one must be especially cautious in extending these findings to other recreational attractions. It seems likely that there are only a very few natural phenomena in the United States about which Americans have such strong feelings. Obvious candidates for this short list include Old Faithful (in Yellowstone National Park) and Niagara Falls.

A companion study of visibility benefits in the eastern United States is presently underway.

Water Quality. In the water quality area, work on recreational, amenity, and existence values is ongoing. An experiment with survey research methods was conducted to elicit both user and existence values attached by people to the national goals set out in the Clean Water Act.

In this undertaking, four different versions of an instrument which depicted levels of national water quality on an eleven-step water quality ladder were administered to subsamples of a national personal interview survey. After a series of explanations and preliminary questions, each respondent was given a card,which contained an array of dollar amounts and was keyed to his or her income through indications of the tax cost of other public programs at that income level. The respondent was then asked what amount, if any, he or she would be willing to pay in higher prices and taxes each year to maintain or to achieve boatable, fishable, and swimmable water in the nation's rivers and lakes. The average annual amounts people were willing to pay (per family) for levels of water quality were: Boatable--$154 (range $138 to $170); Fishable--$189 ($171 to $207); and Swimmable--$218 ($198 to $238).

In connection with recreational values of water quality, an approach to the estimation of the benefits has been developed that bypasses the enormous practical and theoretical obstacles to aggregating site-specific results to the national level. The approach is based on capturing the impacts of changes in water areas available (by state) for different forms of water-based recreation on participation probabilities and extent of participation for individuals across the United States. The method is currently being applied to the projected results of implementing the 1972 Federal Water Pollution Control Act Amendments (as further amended in 1977).

Experiments are also being conducted to see if information concerning what people pay to commercial fee fisheries can be used to evaluate what people would be willing to pay for improved recreational fishing access due to improved water quality.

Comparing Bidding Games with Property Values

As indicated in section III, for the household sector, two distinct approaches to valuation of environmental quality have emerged from recent research. The first involves the analysis of how some actual market prices, such as real property prices, are influenced by environmental quality attributes of the properties. The second, used in one of the studies just described, tries to induce individuals to reveal directly their actual preferences for different levels of environmental quality by means of a bidding game. Clearly, if these methods are valid, there should be a well-defined relationship between what people do pay through differences in property values and what they say they will pay.

A study of the value of air quality in the South Coast Air Basin of California was designed to test and compare these procedures. The results indicate that air quality deterioration in the Los Angeles area has had substantial effects on housing prices and that these are comparable to what people say they are willing to pay for improved air quality. Moreover, the property value estimates are higher than the average bids, which was expected on theoretical grounds.

Based on these results, rough estimates can be made about willingness to pay for improved air quality throughout the South Coast Air Basin. Such a calculation suggests that benefits for a 30 percent improvement in air quality in the South Coast Air Basin may be on the order of a billion dollars annually.

As a caution, however, it should be kept in mind that the South Coast Air Basin studies were conducted in a region where individuals have an exceptionally clear-cut pollution situation that they themselves experienced and where the effect of clean air on property values, and in turn, on the degree to which people are aware of increased housing prices in high air quality areas, appears to be exceptionally well specified.

Application of Econometric Methods to Epidemiology

A substantial effort has gone into the application of econometric methods to epidemiology to try to establish relationships between human morbidity and mortality and air and water quality. In contrast to traditional epidemiology, the application of econometric ideas explicitly recognizes that people make conscious choices about behavior that affect their health, for example, seeking greater medical care in areas where greater risks to health exist. In general, as further discussion of specific cases below will make clear, this effort has not yet yielded comprehensive dependable results. The efforts to relate morbidity to air quality have resulted in even more uncertain results than those pertaining to mortality. Only the mortality results will be discussed here.

Both the air and water studies proceed by estimating an equation of the following general type:

MORTALITY RATE =	F(MEDICAL CARE.	ACE,	GENETIC FACTORS.	BEHAVIOR/HABITS,	DIET,	EXPOSURES)
Heart Disease	Doctors/Capita	Median Age	Race	Smoking	Vitamins	Radiation
Cancer	Hospital Beds/Capita			Room Density	Saturated Fat	Air Pollution
Vascular Disease				Race	Cholesterol	Cold Days
Pneumonia and Influenza					Protein	
Cirrhosis					Additives	
Emphysema and Bronchitis					Alcohol	
Kidney Disease					Coffee	
Congenital Anomalies					Tap Water Quality	
Diseases of Early Infancy						

<u>Contaminants in Air</u>. For the air quality analysis, it was possible to develop a data set in sixty cities containing the variables shown in this equation. The dietary and smoking variables had to be estimated quite crudely, however, for there exist no observations on them. For example, cigarette consumption per capita for a particular city was estimated from cigarette sales tax data for the <u>state</u> in which the city was located. Surely one cannot make any great claims for the quality of these data. It was felt, however, that they were potentially so important in influencing health and mortality that to exclude them would be inviting even more serious error.

In the analysis of air pollution variables, only two statistically significant relationships appeared--between particulates and the pneumonia and influenza variable,and between sulfur dioxide and the early infant disease variable. Both of these are acute effects. The fact that no chronic effects showed up does not necessarily mean that none exist but perhaps only that macroepidemiology with poor data cannot find them. One reason could be that data on the actual air pollution exposure history of people are not available in this country. In view of both changes in environmental conditions and the mobility of the population, current observations of ambient air quality may not be good enough indicators of actual exposure to capture any effects of air pollution on degenerative disease. Another reason is that the results are very sensitive to the "specification" of the equation (that is, to the particular variables which are included). This is a general problem that plagues epidemiological studies using statistical methods.

Taking the results of the air quality study at face value, and applying some of the estimates of what people require as compensation for a small increase in the risk of death (up to $1 million per expected life saved) yields large estimated benefits from air quality control. For a 60 percent reduction in urban ambient concentrations of particulates and sulfur oxides, the numbers range between 5 and 16 billion dollars per year depending on which estimate of the value of risk reduction is used.

Contaminants in Drinking Water. A later effort to identify and quantify the relationship between drinking-water quality and health, which is still in progress, has to some extent become an examination of the broader question of what can be learned from aggregate epidemiology about the relationships between environmental quality and health. Because people are exposed to pollutants through both air and water routes, both air and water quality variables were included. Because health depends not only upon "involuntary" exposure but also upon "lifestyle" choices made by individuals--cigarette and alcohol consumption, and the level and quality of health care services are examples--lifestyle variables were included, as they were in the air study. The drinking water quality variable included was for trihalomethanes, chemical products of reactions between the chlorine used in drinking water disinfection and humic acids present in the raw water. These chemicals are believed to be carcinogenic.

The empirical results so far obtained can be summarized as follows. What is believed to be a plausible range of alternate specification of interrelationships among environmental quality, lifestyle, and quantitative variables was examined. The implied quantitative measures of the importance of the drinking water variable suggests that at least the trihalomethane measure of drinking water quality is insignificant as a determinant of mortality. While some quantitative measures of the importance of the air quality variables suggest that they are indeed important, those measures are unstable over the plausible range of specified interrelationships. Because of that instability, no firm conclusion can be drawn from this study about the probable contribution of air quality improvement to reductions in mortality risk.

Agricultural Damages

As indicated in section III, agricultural production is affected by many influences beyond the control of individual producers. In agricultural regions within or near urban areas, air pollution has in recent decades become one of these influences. As noted there also, when these agricultural regions, say because of unique climate characteristics, dominate the national or regional production of selected crops, output price increases may occur when air pollution reduces crop yields. These price increases will reduce the well-being of consumers. In addition, if increases in market prices are insufficient to offset the reduction in output (demand is relatively elastic), producers may also be made worse off.

Seasonally (mainly in winter and in spring), Southern California produces a major share of the nation's vegetables and fruits. Also, large volumes of field crops such as cotton and sugar beets are grown in the region. The adverse biological effect on many of these crops of the smog that periodically blankets the region are well documented. However, attempts to assess the economic impacts of these effects have been few.

Moreover, those attempts that have been made use the inappropriate method of multiplying the estimated reductions in yields by an invariant price.

A procedure was developed, and applied in Southern California, which accounts for price effects on consumers and producers and for changes in cropping patterns which occur in response to changes in air quality. Among the quantities calculated to reflect damages are changes in consumer surplus and changes in profit. These quantities were calculated with and without 1976 levels of air pollution.

Elimination of 1976 oxidant air pollution and the attendant net increases in aggregate production would have increased 1976 producer profits by about $35 million and consumer surpluses by about $10 million, resulting in an increase of about $45 million in total. This latter figure represents about 3.7 percent of the $1.22 billion total annual farm value of the fourteen crops produced in the area in 1976. While this is a significant amount, it is outweighed by the urban damages in the area, described earlier, by at least a factor of ten.

Acid Rain

Over time, it has become increasingly apparent that rain-out and other types of deposition of materials from the atmosphere are major sources of contamination of water courses. Special interest and concern has come to a focus on acid deposition. When fossil fuels, especially coal, are burned, compounds of sulfur and nitrogen are released along with the other flue gases. Through chemical transformation processes in the atmosphere, these are partly converted to sulfuric and nitric acid. When this acid rains out of the atmosphere or is otherwise deposited in water courses, especially lakes, they may become so acid that they cannot continue to support fish life. Also, increasingly acid soils can affect plant life adversely. Understanding the link between emissions at particular sources and such ecological effects is difficult, and research on the question is in its infancy.

Nevertheless, one of the projects undertaken in the EPA program of research attempted to determine the order of magnitude of the damages due to a very large increase in acid rain, The absolute values of these estimates are of such low probable accuracy that there is no point in reporting them here. However, their relative values are interesting and provide some indication as to where future efforts to produce more refined estimates should be concentrated. It appears from these results that potential ecosystem-recreation damages and potential materials damages greatly outweigh any others that could be identified.

V. Research Needs and High Priority Research Areas

Introduction

In the preceding three sections of this report, we considered the linkages between the EPA's various environmental programs and specific regulations and the resulting improvement in environmental quality, and discussed problems of assigning economic values to improved environmental quality. We also reviewed the state-of-the-art in assessing the economic benefits of reduced pollution, concentrating on research sponsored by EPA's Office of Research and Development. In this section, we outline the research needed to improve estimates of the benefits of EPA's environmental programs and regulations, considering along the way alternative methodological approaches to obtaining the necessary information. We also provide a list of high priority research areas and projects for the next stage of the research.

The discussion in this section is divided into two major parts. The first, part A, considers research needed to develop the relationships between alternative ambient environmental conditions and the values human beings place on these conditions. The discussion is organized around the five major benefit categories described briefly in section II, and for the most part involves the assumption that ambient environmental conditions are given.

The second part, B, of the agenda addresses broader issues of research strategy that relate to EPA's ultimate goal, the improvement of estimates of national aggregate benefits. The focus in Part B is on two major issues: predicting changes in ambient environmental conditions resulting from programs or specific regulations; and the prospects for reducing the uncertainties in national estimates.

Although the two parts of the agenda are treated separately in this section for purposes of exposition, they are not completely independent of one another. The choice of a methodological approach to estimating the value of a change in ambient quality may well depend on what level of aggregation (site-specific, regional, or national) is ultimately desired. Conversely, the appropriate level of environmental detail to seek from models endeavoring to establish linkages between environmental policies and ambient environmental conditions will often depend on the valuation technique to be used as well as on the level of aggregation required.

Research Agenda Part A - The Benefits of Improved Ambient Conditions

This first part of the research agenda concerns itself with research needs in estimating the benefits of given improvements in ambient environmental conditions. The discussion is organized around the five major benefits categories:

- Human Health
- Recreation and Amenity Value (user oriented)
- Existence Value (nonuser oriented)
- Effects on Marketed Goods
- Contingency Value

A special section on benefits of hazardous substances regulation is also included.

Human Health Benefits

People are exposed to pollution and its by-products through beverages they drink, the food they eat, and the air they breathe (in the home, the workplace, commercial establishments, and ambient environment). Two basic steps are involved in estimating the health benefits of reducing the level of contamination via these routes: (1) an assessment of the effects on health expressed through changes in mortality and morbidity (including impaired physical or mental capability, and genetic and reproductive effects), and (2) valuation of these health effects The purpose of this section is to outline, briefly, alternative approaches applicable to the assessment of human health impacts and benefits and to identify especially promising ones meriting new or continued research. Research on health effects will be addressed first followed by a discussion of approaches to valuing improvements in health. An overview of approaches to estimating health benefits is provided in table 1.

1. Direct Human Health Effects

There are essentially two ways to learn about human health effects of environmental contaminants--extrapolation from the results of animal experiments and epidemiological analyses of human experience and exposure. Neither method is straightforward, and the application of either involves controversy over technique and interpretation of results. The approach via animal tests involves disputes over extrapolation from rodent or bacterial models to human responses; whether high doses have qualitatively different effects from low, chronic doses; and whether antagonistic and synergistic effects mean that single chemical tests are of limited utility in the environmental context. It is not clear that this committee can add usefully to these continuing debates and, therefore, while recognizing that animal

Table 1. Overview of Approaches to Estimating the Benefits from Reduced Pollution: Human Health and Related Effects

Benefit Category	Possible Approaches to Estimating Effects	Possible Approaches to Valuation of Effects
	Ambient Environment-User Response Relationships	User Response - Valuation Relationships
<u>Direct Effects</u>		
Mortality Morbidity	Econometric-epidemiology (using macro and micro data sets) Toxicology-animal experiments; bacterial tests	Valuing changes in life expectancy via • Differential wage rates • Health insurance premiums • Cost of public programs intended to save lives Valuing changes in health status via • Differential wage rates • Health insurance premiums • Property value differentials
Impaired Physical and/or Mental Capability		• Workmen's compensation awards; • Cost of health care • • •
Genetic and Reproductive Effects		• Surveys • Costs of health care • • •
<u>Indirect Effects</u>	- - - - - - - - - - - - -	
Losses Suffered by Other Family Members as a as a Result of Morbidity and Mortality	Not Applicable	• Surveys • Value of lost services (court awards for for loss of spouse in accidents, etc.)

tests may be valuable in identifying dangers and in setting research and regulatory priorities, we shall not discuss this method of response evaluation further.

Human epidemiology, based on the unplanned experiments generated by past public and private decisions, is potentially of great value in obtaining quantitative estimates of human response to ambient pollution levels and to acute environmental incidents such as chemical spills. Unfortunately, there remains considerable controversy about the results of investigating this record. The easiest data to obtain is that based on group experience (such as mortality rates for metropolitan area populations), and considerable effort has been invested in analysis of these "macro" data sets. The committee could reach no agreement on an evaluation of these studies or on the prospects for future work. But it did agree that Great Britain is a promising source of such data for an additional test. For several reasons spelled out below, British data on health and exposure to environmental pollution are likely to be better than that available on U.S. populations. A study using British macro-level data and aimed especially at investigating the morbidity and mortality effects of air pollution and drinking water contamination is therefore included as a high priority project. The committee also believes that it would be worthwhile to convene a conference of disinterested scholars, expert in relevant fields such as econometrics and environmental health, to examine carefully the record of macro-epidemiological studies and to attempt a consensus evaluation.

The use of data on individuals ("micro" data) holds considerable promise for epidemiological identification of the subtle effects of pollution on human morbidity and mortality. A possible problem here is that most data sets on morbidity use self-reported disabilities as the measure of health status. But individuals' perceptions of their own disabilities may vary with a variety of psychological and economic parameters (for example, the desire to use up sick leave). Thus, uncertainty about the real circumstances can be considerably reduced if clinical measures of organ systems functions can be obtained and used as the measure of health status whose occurrence is to be explained. A few morbidity data sets do exist that embody measures of organ system function for individual humans, as well as detailed information on medical and occupational histories. They have not yet been exploited in econometric-epidemiological investigations, however. Potentially useful sets include: the Health Insurance Study of the Band Corporation [Brook, et al. (1979) "Conceptualization and Measurement of Health for Adults in the Health Insurance Study," <u>Medical Care</u> vol. 17]; the Seventh Day Adventist data set stored at Loma Linda University in Loma Linda, California; and the Health Examination Survey [National Center for Health Statistics (1973) <u>Plan and Initial Program of the Health Examination Survey</u>, Vital and Health Statistics, Series 1, No. 4 (Washington, D.C.: GPO)].

Another possibility that should be explored is investigation using United Kingdom data on individuals. The existence of the National Health System there, from the late 1940s to the present, has led to a uniform system of data collection for both mortality and morbidity, a system which includes observation on several life style variables such as smoking, diet, and alcohol consumption. Furthermore, the population of the British Isles is apparently far less mobile than the American population. Accordingly, recent measurements of ambient environmental conditions should reflect exposure history more adequately than for the population of the United States. In early contacts, the British authorities have proved very cooperative. A British data set should be assembled and analyzed using the best statistical techniques available.

A further source of epidemiological data and insights that remains to be explored in a systematic way is the relation between workplace exposure to contaminants and subsequent morbidity and cause and timing of death. Asbestos, synthetic chemical, and dry cleaning workers may serve as a basis for extrapolating a known hazard from a small population exposed to a high dose, to a large population exposed to a low dose. Special purpose studies have been done in this area, but often by interested parties in disputes over liability, and an objective investigation of the availability of data on exposure, health and mortality, and on income, life style characteristics, and other presumably important independent variables is in order.

Indeed, in analyzing the relationship between levels of contaminants in the ambient environment and human health effects, the aim should be to consider total exposure--the composite of all indoor and outdoor exposures. This includes exposures in the home, in public and commercial buildings, and in the workplace, as well as in the ambient environment. Recent studies indicate that the levels of pollution in schools, hospitals, and residences are a function of fuel use, ventilation rates, types of applicances, and outdoor concentrations of pollutants. How to develop a measure of total exposure under these complex circecumstances is a difficult research topic in itself.

2 . Valuing Human Health Effects

A central question for estimating the benefits to human health of reduced pollution has been and remains what value to place on reduced mortality (increases in life expectancy) and morbidity. How much would people be willing to pay for a reduction of their risk of earlier death or increased illnesses, or how much would they have to be compensated to voluntarily accept an increase in this risk?

Mortality. The benefit of reducing the risk of earlier death is not precisely known, and perhaps will never be, since attitudes--especially willingness to accept risk--presumably can change over time, between groups, and can vary in different risky situations. But there exist several potentially useful approaches to valuation. These include: differential wage rates and property values, insurance risk premiums, costs of public programs intended to save lives, survey responses, and, possibly, other behavioral responses to risky situations such as seat belt use. The application of the wage-differential technique has, as explained in section III, at least produced a range of values for an expected life saved--from about one quarter to one million (1978) dollars--that at least allows us to bracket within an order of magnitude the potential benefits of reducing environmental risks involving mortality. But we know that deficiencies may exist in the studies that produced these numbers. For example, they may be focusing on the least risk averse part of the population, and they may not be relevant to situations involving involuntary risk. Furthermore, they do not deal with the nature of the sickness producing death (the "quality of death"). And they do not address the monetary and psychological costs that a death imposes on others still living.

These problems should be addressed in future research.

Morbidity. Valuing the effects of pollution on morbidity is a challenging task because the range of possible damaging effects is so diverse. For example, there may be adverse effects on labor productivity either because a person is actually physically ill, or, more indirectly, because of his or her physical or mental abilities have been impaired' by exposure to environmental contaminants such as lead. Other damages include the medical costs of treating illness, the psychic costs to the victims in terms of pain and frustration, and disutilities imposed on others, especially family members, due to an illness. It will take innovative and ingenious research to quantify these types of damages, and an effort seems merited since preliminary research suggests their magnitude may be quite large.

In some cases it may be possible to shortcut the actual linkage between pollution and disease by estimating the relationship between ambient environmental conditions and such variables as productivity and medical costs directly, without the intervening step. This possibility seems well worth exploring.

<u>Losses suffered by other family members as a result of morbidity and mortality</u>. This is another very difficult area though again it is possible to conceive of survey approaches that might yield useful results. Measures based on lost earnings or lost services (e.g., housekeeping) could provide lower bounds. The pain and suffering aspects might be intractable, though some rough bounds might come from court awards to survivors of accident victims.

3. <u>High Priority Research Areas</u>

- Further testing of macro-epidemiological methods using British data
- Conference on evaluation of existing macro-epidemiological studies
- Econometric-epidemiological studies of morbidity and mortality using micro-level data from the United States and Great Britain.
- Pilot study of potential for extrapolating pollution health effects from workplace exposure.
- Further work on valuation of health effects
  - implications of differential levels of risk aversion in population;
  - effect of involuntary nature of risks
- Refinement of methods for valuing morbidity damages, including losses suffered by other family members

4. <u>Data Generation Needs</u>

Two important questions implicit in the above discussion of study possibilities and related data inadequacy are: What kind of data would be better? And, is it worth incurring the cost of assembling such data from existing sources or from individuals directly? Regarding new data sets, there are two major alternatives in addition to the assembly and exploration of British data as described briefly above.

One such possibility might be called the creation of "piggyback" panel data sets. This effort would build on existing data sets by assembling additional, complementary data on the units of observation, resulting in a data set suitable for studying relationships between health and environmental quality. By using existing data on most, or at least many, variables of interest, the costs of assembling a panel data set are substantially reduced, with data generation costs incurred only for the additional variables.

Feasibility of the piggyback idea depends, of course, upon the existence, availability, and quality of large health status panel data sets. Several candidate sets have been identified, both in the United States and abroad--particularly in the United Kingdom and in Sweden. But no systematic examination of their suitability for econometric epidemiology, and of the costs of assembling the complementary variables that may be necessary to make them suitable for such work, has been undertaken. Such a systematic examination is a step toward assessing the prospects of piggyback econometric epidemiology. After such an examination, the costs and potential value of such work can be brought into focus. The methods for estimating those costs, and that potential value, will be identical for both piggyback panel studies and panel studies built on newly collected data. For that reason, we discuss only the latter here.

In order to estimate the cost of a panel data set suitable for studying relationships between human health and environmental quality, assumptions about the size of the effects we are looking for, and about characteristics of the sample, must be made.

Suppose that we are looking for effects responsible for 50 additional deaths per hundred thousand individuals in the age cohort 50-65. Simple statistical arguments then suggest that a "panel"-- a group of individuals observed over time--would necessarily be of size 5,000 to 10,000 if there is to be any hope of establishing, or rejecting, claims that effects of this size are present.

The reader should be warned that a poorly-designed panel study run at whatever cost can yield useless information. The design of a good panel study--selection of panel participants, of variables for observation in interviews and physical examinations, and choice of data base management methods--is itself a major enterprise. It should be noted that the results of a successful panel study of this type might be of great importance not only to efforts aimed at an understanding of the relationships between environmental quality and health, but also to efforts to understand the determinants of human health in general.

5. High Priority Data Gathering Project

- A single cross section or continuing panel study of the health of 10,000 selected individuals in the United States population.

Recreation and Amenity Benefits

The recreation and amenity benefits of pollution control are limited in this report to those deriving from direct use of environmental resources. In this respect, they differ from existence and contingency value benefits, described below, which derive not from direct use, but from the knowledge that the environment is getting cleaner or that future options are being preserved.

Within the category recreation and amenity, there is a further necessary distinction. In recreational activities, the environmental "backdrop" has an amenity value (e.g., a walk along a clean river is probably valued more highly than a walk along a polluted stream), and we subsume this in the valuation of the activity itself. But the environmental backdrop for all activities of daily life may also be presumed to have value. These amenity values are to some extent, and in certain cases, included in property value differentials, and though one would not expect that they could be disentangled from other sources of such differentials, for certain aggregate benefit estimation problems this may not matter.

An overview of possible approaches to estimating recreation and amenity values is provided in table 2.

1. Water-based and Water-backed Activities: Recreation and Amenity.

Recreation Participation Rates and Valuation. Here we consider recreation in its more conventional sense--as a voluntary participation activity. One traditional approach to the economics of outdoor recreation searches for the determinants of the decision to participate in an activity. In the context of water pollution control benefits, the relevant idea is that the quality of the water available for a particular recreation activity--or the quantity of water of a given quality--influences the decision whether or not to participate and how much time to devote to participation.

Table 2. Overview of Approaches to Estimating the Benefits from Reduced Pollution: Recreation and Amenity Value

Benefit Category	Possible Approaches to Estimation of Effects: Natural Systems Models	Possible Approaches to Estimation of Effects: Ambient Quality User-Response Relationships	Possible Approaches to Valuation of Effects
<u>Water-based Recreation</u> • fishing • boating • swimming <u>Water-backed Recreation/ Amenity</u> • picnicking • walking • viewing	Water Quality Models	Changes in participation rates	Valuation per participation unit: • travel costs • surveys • demand functions from fee sites
		• <u>User</u> demand functions from user surveys • <u>Site</u> demand functions from site surveys or travel cost methods. • Hedonic travel cost method	
<u>General Amenity</u>			
• visibility	Air Quality Models	• Property values	
• odor		• Surveys	
• scenery	Water Quality Models	- bidding games - anchored estimates	
• noise	Noise transmission models	- rank orderings	
• litter	Not applicable	- public budget reallocation	

The conventional unit for the participation variable is the activity day. Prediction of the level of activity days is one part of the participation-based benefit estimation method, and putting a value on those days is the other. At least three valuation methods present themselves as alternatives. One is a survey technique in which the questions probe willingness to pay for a day of the activity in question. (This has been attempted by the U.S. Fish and Wildlife Service in its quinquennial surveys of fishermen and hunters.) A second is the direct measurement of a demand function based on data from places at which people pay fees to indulge in (the) particular activities. (There is a problem in applying this method to the United States, for it seems to be true both that very little water-related recreation has a price attached to it and that that which does is qualitatively different from the "free" recreation available more widely.) A third valuation method involves the application of the travel-cost demand estimating technique. In this technique, a method is used to infer willingness to pay from time and monetary costs actually incurred by persons who come to use a particular recreation site.

Other methods of valuing recreation benefits from pollution control include the use of property value differentials for land surrounding recreational water bodies, and the hedonic-travel cost technique. The latter uses data from many markets, therefore has much more global robustness than standard hedonic studies which look only at one market. The technique, by its nature, avoids the criticism raised against standard approaches -- that they can't provide the value of improvements if quality is improved across a community. The technique also avoids the need to estimate the opportunity cost of time, a problem which greatly has troubled some other approaches. Finally, by focusing on inputs not outputs, it relies on objective measures, not subjective measures, and it avoids completely the criticisms raised against the use of the household production framework when time matters. It deserves further investigation in the national benefit context.

2. Amenity Values

As indicated above, "amenity" is used in this section to refer specifically to the background for the activities of everyday life rather than to the background for voluntary recreation activities. One possibility for evaluation is based on property values--the differential value of a home or other piece of property reflecting, among other things, the attached amenities (see sections III and IV). There is the difficulty, however, that any property value differential attached to pollution will presumably reflect an amalgam of several kinds of effects, such as health, as well as amenity (visibility, odor, litter). If we want a total amenity value, we may not, for this reason, be able to get a component of it via property values. And further, it will generally not be possible to add total benefit estimates based on property values to other benefit categories,such as health effects,because of the danger of double counting. Nonetheless, there are circumstances in which this will not matter -- for example in valuing a geographically localized policy change -- and some further experimentation with the technique as a summary measure of several effects is merited. National benefits estimation from a large number of property value studies may become increasingly feasible as the Market Data Center in Los Angeles, whose data were used in the Los Angeles study reported in section IV, continues to add new cities in a program to develop a national data bank of home sales information. An analogous technique is the analysis of wage differentials in areas with different levels of amenities and of environmental quality. Presumably, a higher level of amenity permits less compensation for a given amount of work, other things equal.

Other techniques for amenity benefit estimation include various survey formats. Four major alternatives are: bidding games, "anchored estimates," rank ordering, and public budget category reallocation. Each of these appears to have both promise and problems, and as described below, we recommend that research on developing the promise and reconciling the problems receive high priority over the next several years.

Bidding games are designed for use in very specific situations, situations that can be described in pictures (see sections III and IV); hence, their frequent use in visibility studies--i.e., when the question involves the value of a particular vista.

"Anchored estimates" is a name recently given to a survey technique in which the cues to the respondent are deliberately made less specific than in a bidding game (e.g., general verbal descriptions of contrasting visibility conditions throughout an area rather than at specific sites under different environmental policies). A key question is clearly, then, how much difference the specificity of the hypothetical valuation situation makes, for both bidding games and "anchored estimates" face objection on the grounds of the strategic bias (see section III) created by questions about desires and willingness to pay for public goods, and they differ in the degree in which they tie down what is being valued.

Similar objections also apply to survey questions in which rank orderings of outcomes are sought; and in which spending in public budget categories is reallocated by the respondent.

Because these techniques may allow us to get at benefits categories very difficult to approach by more conventional techniques, further investigation, evaluation, and comparison deserves high priority in any future research program.

3. <u>High Priority Research Projects</u>

- Analysis of property value and wage differentials in the valuation of environmental amenities
- Experiments in valuing the same amenity features using two or more survey methods

  [For example, one could use two national samples to value protection of visibility at Bryce Canyon National Park, giving one sample a set of photographs "covering" the Park and the other a verbal description of what is involved--all other cues and operations to be the same. More elaborate versions of such experiments can be imagined.]
- Small panel experiments comparing two or more survey techniques in a carefully controlled setting

[If one accepted that the results of bidding game techniques were the standard, then such comparisons would tell how far off the other survey techniques were. Several such experiments might begin to show whether there was a bias to this "inaccuracy" or if it was a matter of larger variance in results.]

4. Data Generation Needs

Methods of benefit estimation based on participation and its determinants may begin with micro data (on individuals) who either do or do not participate in the activity in question, or from more aggregated data on groups, in which case the relevant variable is the group's participation rate. To our knowledge, there is no nationally applicable data set of either kind satisfactorily covering any pollution-related activity other than recreational fishing, and wider application of methods resting on changes in participation will depend on the generation of such data. In particular, a survey should be designed and carried out that would provide data at least on participation in water-based and water-backed recreation activities along with necessary information on residence and socio-economic characteristics of the respondents. Such a survey should provide enough observations and enough information per observation to allow the estimation of cross-section participation equations using state-level (or finer) water quality availability data. A more elaborate undertaking would also involve determining specific locations at which the participation occurred (e.g., on which stretch of which river the respondent boated or in which lake he or she swam).

5. High Priority Data Gathering Project

- National participation survey for water-based and backed recreation

Existence Values (nonuser oriented)

Existence values are limited in this report to those deriving, not from direct use of environmental amenities, but from the intrinsic value people place on them and on the knowledge that the environment is getting cleaner or being preserved. Existence values stem from heritage, national pride, or ethical attitudes concerning nature; also from historic, artistic, and scientific concerns. In estimating existence values, no direct use of the environmental amenity being valued is anticipated. Existence value is distinguished from contingency value (discussed below) in that the latter is valued in terms of uncertainty about whether the environmental amenity *might* be of direct value sometime in the future.

For levels of environmental pollution and information on related environmental effects, only one step is involved in estimating the existence value benefits of reduced pollution--the valuation step. Because direct use of the environment is not anticipated, it is neither necessary nor possible to estimate the effects of pollution on human use patterns. Approaches to estimating the benefits of existence values are summarized in table 3.

1. Valuing Pollution Effects

In the context of measuring the benefits of controlling environmental pollutants, existence values can take several forms depending on what aspect of the environment is being preserved or enhanced.

Table 3. Overview of Approaches to Estimating the Benefits from Reduced Pollution: Existence Values

	Approaches to Evaluating Effects	Approaches to Valuation of Effects
Benefit Category	Ambient Environment-User Response Relationships	User Response - Valuation Relationships
Scenic and recreational units	Not applicable	Valuing existence or "knowledge" effects
A clean environment		• Surveys - anchored estimate - bidding games - rank ordering - public agency budget reallocation
Preservation of specific species Ecological diversity and related effects		• Contributions to single and general purpose conservation type organizations

Scenic and recreational units. People may have a measurable willingness to pay to preserve specific scenic and recreational units such as the Grand Canyon for the general use of mankind and future generations. The concept of existence value is equally applicable to man-made structures and artifacts of historical or artistic/ aesthetic significance. Preliminary evidence cited in section IV concerning the visibility near the Grand Canyon suggest that existence values for some scenic units and amenities may be very significant.

One approach to measurement is to employ nonmarket bidding games and other survey techniques, and this approach is well worth developing further. But it would also be highly desirable to develop alternative measures based on actual behavior rather than on responses to hypothetical questions. For example, while contributions to general purpose conservation organizations, such as the Sierra Club and the Natural Resources Defense Council, and single purpose organizations, e.g., Save-the-Redwoods and Nature Conservancy, provide evidence in support of the hypothesis that existence value is a meaningful idea, it is a subject for research whether means can be developed for analyzing this evidence to separate the existence values from option values and user values, and to establish a basis for extrapolating from actual contributors (which may represent a subset of all those with positive willingness to pay) to the population as a whole.

A clean environment. Preliminary work using the anchored estimate technique provides evidence that individuals have a willingness to pay to assure the existence of a clean environment generally. Future research in this area should be directed to refining the survey questionnaires to provide better definition of the alternative environmental states being valued, and to determining the extent to which reported values incorporate benefits related to the individual's own actual or possible future use of the environment.

Ecological diversity and other subtle effects. The value of information in gene pools and the scientific research value of particular ecosystems is not likely to be recognized by the average individual. Therefore, bidding games and other survey techniques may not be fruitful in estimating the benefits of this category of existence value. Are there other approaches to valuing ecological change which are capable of yielding meaningful monetary measures of ecological values? One possibility is to value changes by the cost of replacing lost natural ecological functions such as biomass growth or nitrogen fixation. It is arguable that replacement cost is a valid measure of economic damage only if that function would in fact be replaced; that is, if people found the function to be sufficiently important, in some sense, to be willing to incur the replacement cost if the natural function were lost. This argument raises both ethical and economic issues which need to be explored at the conceptual level.

2. High Priority Research Projects

- Additional survey research on the value of major scenic and historical sites which are, or may be, affected by pollution.
- Conceptual and empirical study of potential use of contribution and membership data from environmental organizations for existence value purposes

- Conceptual underpinnings for use of survey techniques, including bidding games, in species preservation and subtle ecological contexts. This includes comparison of survey and replacement cost valuation techniques.

Effects on Marketed Goods

The benefits of reducing the effects of pollution on marketed goods are derived from the costs of producing them and the demands for them. As discussed in section III using agriculture as an example, in principle, two steps are involved in making this assessment: (1) determining the physical effect of pollution on the marketed good, and (2) assessing the loss in value associated with this effect. Sometimes it is possible to eliminate the physical effects step by relating increased costs directly to pollution. Approaches to estimating the benefits of reducing damages to marketed. goods are summarized in table 4.

1. Valuing Effects on Marketed Goods

Agriculture. Information on the relationship between crop damage and levels of ambient environmental pollution is seldom available, or at least available in a form usable in benefits estimation. (That this is not always true is illustrated by the case study of Southern California agriculture reported in section IV.) Output levels and input prices in agriculture are more readily observed, and thus reported, than the corresponding dose-response functions. This is particularly true where individual farm budget data are

Table 4. Overview of Approaches to Estimating the Benefits from Reduced Pollution: Effects on Marketed Goods

	Approaches to Evaluating Effects		Approaches to Valuation of Effects
Benefit Category	Natural Systems Relationships	Ambient Environment-User Response Relationships	User Response-Valuation Relationships
Agriculture	Air and Water Quality Models	Dose-response relationships	Valuing damages to marketed goods • changes in product costs
Materials (homes, buildings, bridges, automobiles, etc.)			• Increased repair costs, shorter lived products
Commercial fisheries			• Demand analysis
Water supply (domestic, commercial industrial			• Increased "treatment" costs for inputs.
Power Generation			

collected by agricultural experiment stations, as is the case in nearly every state. Even though the recurring value of pollution-induced damages to crops appears to be small compared to some other categories of damages, the ease of estimating cost functions, and the readily available data for estimation, make the cost approach a worthy candidate for further research.

Materials. Decay of masonry, corrosion of metals, weakening of plastics, discoloration of fabrics, and other forms of material degradation apparently represent a considerable loss attributable to pollution. Crude engineering estimates put these damages at a substantial fraction of the total due to pollution. Moreover, these estimates do not include damages to historical treasures, works of art, and libraries. Though the physical laws relating to the degradation of materials are reasonably well quantified, and though these effects are known as a function of location, attempts to translate the effects into benefits of pollution control are handicapped by a lack of valuation tools. There are relatively few clear-cut material choices induced by pollution, and little is known about the wide range of producer and consumer material substitution, with subsequent changes in product life, as a function of pollution levels.

The development of methods for estimating national aggregate damages accruing via materials damage due to pollution is a formidable job. A pilot project aimed at methods development seems advisable before the very large sums are committed that would be necessary to gather and manipulate data on use, substitution, and loss from deterioration across material or product classes and geographical regions.

Such a pilot effort should have high priority.

Commercial fisheries. Because of the comparatively small market in commercial fisheries affected by the EPA's environmental programs, the relevant benefits appear to be small relative to the other categories. Consequently, no additional research is recommended.

Water treatment. Environmental pollution increases the costs of water treatment. The benefits of reduced pollution in this case are represented by the treatment costs avoided. In principle, this is a straightforward computation, although the data might not be readily available. Nevertheless, no further economic research seems to be necessary.

Power generation. Once more, the likely damages are judged too small to justify assigning a high priority to research in this area.

2. High Priority Research Projects

- Damages to agricultural products: development of farm cost functions with ambient pollution levels as arguments
- Damages to materials: pilot project on methods for estimating effects and for valuation of those effects.

3. Data Generation Needs

Data from the laboratory on the response of samples of materials to specific pure pollutants is not easily translated into effects on machines, equipment, and structures in use in the economy. Complications such as the synergistic and antagonistic effects of other pollutants present in ambient mixtures, and the presence of other materials and partial shielding, create serious difficulties in assessment.

Further, material damage may or may not have observable economic effects. It is one thing to observe that copper rain gutters corrode faster and must be replaced more often in the presence of acid precipitation. It may be quite another to observe that auto finishes are damaged, for other parts of the auto may wear out and force its retirement long before any acid rain effect is significant.

Accordingly, it seems desirable to undertake studies of material damage in practical situations. Because, however, it is unclear at this time how best to proceed, and because a full scale data-gathering project in this area could be very expensive indeed, it seems wise to begin with several pilot projects. These would be aimed at preliminary determination of the importance of pollution-induced material damage in several sectors: households, commercial enterprises, and industry. Surveys of the experience of individual units in those sectors seem to be a promising way to begin.

4. High Priority Data Gathering Projects

- Pilot surveys of pollution-induced material damage in several economic sectors.

Contingency Benefits

Contingency value is associated with potential impacts on the environment where the effects or value, or both, are unknown at the time the benefits are estimated but where they clearly might occur or exist. Two major components of contingency value are option value and anxiety value. Possible approaches to estimating contingency value are shown in table 5.

Table 5. Overview of Approaches to Estimating the Benefits from Reduced Pollution: Contingency Values

Benefit Category	Approaches to Valuation
Option Value - Species diversity - Genetic pool - Historic value - Scientific value	• Surveys of willingness to pay (or to be compensated) • Natural hazard analogs • Crime and other social analogs
Anxiety concerning potential major environmental episodes	

1. Valuing Contingency Effects

Option value. Several classes of environmental policy aim at preservation, for future possible use, of environmental or natural resources the loss of which might be significant and irreversible. One example is furnished by the preservation of free-flowing rivers: once a river is dammed for hydroelectric power, or impounded to create a reservoir, it is virtually impossible to restore that river to its natural state. Another example is furnished by species extinction.

Special conceptual and empirical problems arise in attempting to quantify the benefits of such policies. Simple measures of current use of,and corresponding estimates of current demand for, the environmental or natural resource will typically understate economic value. This happens because some value is attached to preserving the opportunity to use the environmental or natural resource in the future, particularly if time should prove the environmental resource to have some unique characteristics, or the natural resource to have some unique uses. For example, demand for the recreational services of free-flowing rivers has increased rapidly in the past decades and may continue to increase. Postponing development until more information on the rate of increase in demand is available may be warranted. Similarly, new medicinal uses of chemicals produced by or from plant and animal species are continually being discovered. Species extinction may eliminate natural compounds of substantial future value.

In the last few years, economic theorists have done much toward formalizing these notions. But we are aware of no successful or promising application of these ideas to assessment of the benefits of pollution control policies. Clearly, environmental deterioration may reduce options; for example, a polluted lake may reduce the range of fishing options open to anglers who have never fished, but might someday want to fish, in it. Since other methods of valuation may not capture option values, it is important to conduct research to assess their significance with respect to environmental quality.

Option value is, in some important respects, close to existence value as a source of benefits. The difference is the central role in option value of uncertainty. This suggests that suitably modified versions of the survey methods discussed in the existence value section should be explored here as well. The challenge will be capturing the uncertainty aspect without going beyond the rather narrow limits of people's ability to process and understand probability information. As for techniques based on contributions to environmental organizations, one must doubt that it would be possible to separate existence and option value as motives, except by resorting to survey methods applied to members. But for aggregate national estimates, separation may not be necessary.

Anxiety value. Another type of environmental hazard is coming into increased prominence; that associated with environmental "episodes." In such instances, risk valuation has some special features that remain to be explored. On the one hand, the natural hazards literature suggests that most of the time people systematically misperceive and, for the most part, underestimate, the hazards they face in daily life. They achieve this very largely by ignoring or distorting information on which they could base subjective probability estimates, or by refusing to think in probabilistic terms at all.

Such behavior may help people to deal better with anxiety or it may simply reflect the difficulty of coming to grips with probability concepts. On the other hand, the Love Canal incident may show that in the midst of a continuing "incident", probabilities of danger are systematically <u>overestimated,</u> and anxiety thus increased. It seems likely that such anxiety will turn out to be one of the major effects traceable with certainty to the Love Canal incident, to Three Mile Island, and to the Kepone contamination of the James River. It also seems at least worth exploring the possibility that even if systematic distortion of probabilities is taking place, a generalized continuing anxiety about carcinogenic substances is creating continuing damage in society at large, even among those of us who have not (yet) been directly affected by an "incident". Lessening such anxiety through the provision of rules about use, handling, and disposal of hazardous substances could be a major benefit of the federal legislation and implementing regulations dealing with hazardous materials. (More is said about this below.)

Is is possible to estimate benefits from anxiety reduction? There are some possibilities. They include working from natural hazard analogs, such as floods, to find the imputed value of reducing the probability of "an incident" affecting a particular population; looking for analogs in other sources of society-wide anxiety, such as crime; attempting comparative property value studies around sites with potential to cause "incidents" and similar areas lacking such sites; and investigating the costs of ex post reactions to incidents. With respect to the last, often the public response to extreme events, if they are thought to be controllable, is to make new administrative rules and legislate new regulations. Such new rules impose costs on companies, agencies, and consumers. It could be informative to select a few of these unusual events, identify the consequent important changes in rules and regulations, and estimate the cost through time of these changes on those affected.

Valuing anxiety is a novel, apparently important, and most difficult area--one in which there is a strong need for innovative research.

2. <u>High Priority Research Areas</u>

- A pilot project on extension of survey techniques, including bidding games, to deal with option value and anxiety.
- Systematic review of natural hazards literature for applicability to option and anxiety values.
- Review of literature on other social problems intrinsically involving uncertainty.
- Exploratory studies of comparative property values near hazardous sites
- Exploratory studies of legislative reaction to extreme events and the subsequent costs imposed by legislation.

<u>Benefit Analysis of the Toxic Substances Control Act (TSCA) and the Resource Conservation and Recovery Act (RCRA)</u>

In the last decade both public and legislative attention have shifted from an almost exclusive concern with the more familiar and conventional air and water pollutants. There is now general concern with, and debate over, the somewhat novel problems' posed by hazardous materials. It seems worthwhile to comment here briefly on the analytical problems that will face efforts to estimate the benefits of programs aimed at the control of hazardous materials.

Two major pieces of enabling legislation are the bases for EPA's hazardous substance control policies: the Toxic Substances Control Act (TSCA) and the Resource Conservation and Recovery Act (RCRA).

1. The Toxic Substances Control Act

In principle, TSCA can, like any other set of government policies and practices, be subject to benefit analysis; that analysis could proceed either at the level of regulation of a particular chemical or group of chemicals, or at the level of TSCA implementation practice as a whole. Let us consider how benefit analysis would proceed--in principle--at each of these levels. For a particular chemical or group of chemicals subject to regulation under TSCA, benefits are simply the damages avoided by the policy--ranging from use restriction to withdrawal from commerce--announced by the Administrator. The relevant damage categories are enumerated in TSCA and include, for both occupational and general population exposures, the health and environmental damages associated with use levels and patterns of an existing chemical--or projected use levels and patterns of a new chemical.

For a set of methods, practices, and decision rules, which together constitute TSCA implementation policy, the definition of associated benefits is conceptually clear. The relevent measure is the aggregate of damages to health and the environment avoided by those policies.

But the difficulties of translating these concepts into dollar benefit measures, while familiar in other benefit estimation exercises, are much more severe here. Begin with estimation of the benefits of regulation of a particular existing chemical under TSCA. For an existing chemical, health benefit estimation requires estimates of exposure levels, dose-response relationships, and a method for valuing health damages. For a new chemical, the problem is even harder: an estimate of health damages avoided requires an estimate of the exposures that would have occurred had the chemical not been regulated. Though firms routinely make market penetration estimates for new products, such estimates are notoriously difficult for genuinely novel products.

Finally, consider estimation of the benefits associated with the set of regulations and practices that is TSCA taken as the policy. An additional task must now be added to the tasks listed above: the benefit analyst needs a model of the TSCA implementation process. For what has been done under TSCA last year may be a poor guide to next year's TSCA implementation practice. If we can make plausible assumptions about future TSCA practice, then damages avoided, and hence benefit, estimates can, at least in principle, be made.

2. The Resource Conservation and Recovery Act

At the heart of RCRA is a system for tracking hazardous substances from initial generation to final disposal. The benefits associated with RCRA implementation are, again, the damages avoided by the implementation system, computed with respect to the damages that would be imposed in the absence of RCRA.

Most observers of the unfolding RCRA implementation process believe that several years experience may be necessary before much can be said with confidence about that process. Nevertheless, it is clear, even without that experience, that benefit analysis of whatever RCRA implementation process emerges will face at least one serious and identifiable difficulty. In particular, because we know so little now about the level and composition of hazardous waste generated, and so little about disposal practices, the "no RCRA zero point" will be poorly defined.

3. High Priority Research Projects

- Projects directly related to these acts and their implementing regulations are described above under "human health benefits" and in part B, below, as part of the discussion of tracing the implications of regulations for discharges or releases.

RESEARCH AGENDA Part B -- Research Strategies

Introduction

Part A of this research agenda concentrated on problems of estimating human responses to pollution and the valuation of those responses. As should be evident from that discussion, there is still a great deal to be done in this general area before we can be at all confident of our ability to deal with such difficult and subtle sources of benefits (damages avoided) as human health effects, and anxiety, option, and existence values.

Given, however, that the EPA's ultimate interest is in national benefits estimates for national programs and regulations, it would not be sufficient to concentrate only on this last part of the benefit function. It is also necessary to devote some attention to: (1) problems of predicting ambient environmental conditions, with and without the environmental programs and regulations; (2) ensuring that the spatial and temporal resolutions of pertinent indicators of ambient environmental conditions are consistent with the resolutions and data demands of the evaluation techniques used in the five major benefit categories (discussed in the first part of the research agenda); (3) problems of aggregating benefits across individuals and consumer groups, sites and geographic regions, and benefits categories to produce national totals; and (4) prospects for reducing the uncertainties in national estimates.

The second part of the research agenda addresses issues of research strategy, as yet unresolved, that arise out of the EPA's goal to improve estimates of the national benefits of its environmental programs and specific regulations. Thus, in this part, the benefits estimation problem is viewed as a system of components to be analyzed and combined in the most appropriate ways to produce national estimates. Uncertainties are inherent in aggregate benefit estimates, but research can reduce the uncertainty of any particular component, and an important strategic question is how to get the most improvement in confidence per dollar of research funding.

To begin to answer this question, we must address two topics in a little more detail: (1) the relationships between the EPA's environmental programs and policies and the resulting ambient environmental conditions; and (2) opportunities for reducing the uncertainties in national benefits estimates as expeditiously as possible. The first involves research needs in benefits estimation that were not addressed in Part A; the second takes a systems view of the national benefits estimation problem and delves into an area where issues of data availability, consistency in information and in the resolution of that information among the major linkages in benefits estimation, aggregation, and uncertainty are central.

Impacts of the EPA's Programs on Ambient Environmental Conditions

To estimate the benefits of an EPA program or regulation, it is necessary to establish two alternative ambient environmental states--one with the program or regulation and one without it. This is true of benefit analyses conducted both before (ex ante) and after (ex post) implementation, although the requirements implied by the two situations differ in some respects. For ex ante analyses, one must predict the resulting future states of the ambient environment. For ex post analyses, one must be able to assess the state of the ambient environment assuming the program or regulation had never been adopted. Both analyses require, in principle, two steps, as described briefly in section II: (1) analyses of the relationship between the program or regulation and discharges of pollutants or releases of contaminants to the ambient environment, and (2) analysis of the relationship between discharges and releases of pollutants and contaminants and resulting ambient environmental conditions (the natural systems relationships).

1. <u>From Program or Policy to Discharge</u>

For ex ante benefit analysis, it is generally not possible to find in the act or regulation a complete specification of the resulting discharge or release levels, even though there may be substantial and detailed guidelines from Congress or the Administrator of the EPA. Thus, for water pollution control, the published regulations do provide fairly specific guidelines for predicting what the permitted discharges of any particular set of existing (and contemplated new) sources should be. But even here considerable flexibility is left to the permit-writing stage, and thus ex ante analyses contain an unavoidable element of uncertainty for this reason. Such uncertainty is magnified greatly by the design of the air pollution control system with the flexibility available for states' handling of existing sources.

Predicting the effects of toxic substance and hazardous waste regulations is yet another matter. One reason for this is that neither the EPA nor anyone else has indicated how the information that will be collected and transmitted to the Agency as a result of the regulations will be used to identify and address potential environmental problems that would go unaddressed in the absence of these rules. For example, how will the Toxic Substances Control Act (TSCA) and the Resources Recovery Act (RCRA) enable the EPA to nip future "Love Canals" and toxic chemicals crises such as the Michigan PCB problem in the bud? How will these regulations induce the changes in behavior that are the essence of this initial link in the chain of "regulations-to-dollar-benefits?" This has nothing to do with the effects of hazardous wastes on either human health or on ecological life support systems, nor with the way such changes should be valued. Rather, it involves the changes in probabilities and in the extent of accidental or intentional discharges and of exposures to potentially hazardous substances.

Analysis of all environmental programs and regulations is further complicated by the necessity of separating their effects from exogenous changes in conditions that affect discharges. The classic case of confusion in this regard is the British experience with "anti-smoke" legislation and the confounding of its effect with the pre-existing trend away from coal and coke and toward natural gas in home heating. An ex post examination of the actual benefits to be attributed to U.S. air pollution control efforts would face a similar problem of disentangling the effects of the attractive relative (regulated) price of natural gas from those of the various versions of the Clean Air Act. In ex ante analyses, conceptually similar problems arise, for where discharges are not constrained in total but only via new source performance standards and the like, economic growth can produce lower air quality, other things remaining the same. Thus, the analyst must be careful in defining the "with" and "without" situations to avoid biasing the benefits estimates.

The ability to translate program or policy into discharges and releases is essential to benefit estimation. It is particularly difficult but also particularly important for those programs intended to control discharges and releases of toxic substances and hazardous wastes. Yet virtually nothing is known about this linkage. It should be considered a primary target of opportunity for benefits research at the EPA.

2. The Pollutant Discharge-Ambient Environment Relationships

An enormous amount of research effort over the past six decades has gone into the development of analytical models and other quantitative relationships for predicting ambient environmental conditions resulting from discharges of pollutants The earliest research, beginning in the 1920s; involved the development and application of water quality models. This was followed, in the 1950s, by the development of air dispersion models. The 1960s and 1970s, partly as a result of the increased awareness of and concern for environmental quality, but more importantly the increased research budgets more generally and the widespread availability of digital computers in particular, witnessed substantially increased activity in the development and application of natural systems models. Moreover, this field has been so active in the past ten to fifteen years that it is virtually impossible to keep abreast of the latest developments and applications.

Thus, the pertinent issues here concerning research on natural systems models and relationships, the second major linkage in benefits estimation, is not whether the EPA is supporting such research, but whether the research that has and is being supported can be used in estimating the national aggregate benefits of its program. For the most part, the development of natural systems models has involved fairly detailed spatial and temporal resolutions--from a few hundred to a few thousand feet, and from a few hours, to a few days, to a single season of the year. This level of detail has, in the past, made sense, for many important environmental impacts are local, lasting for a relatively short period of time. Averaging over larger spatial and longer time scales could miss completely a significant portion of the benefits of pollution control. But this level of detail could strain even the most generous research budgets where national benefits are the goal.

Consider, for example, the construction of a "national water quality model" designed to translate spatially differentiated pollution discharges into a comprehensive national picture of the resulting water quality. Such a model would have to reflect a certain degree of spatial disaggregation along individual rivers, streams, and lakes in order that even rough approximations to actual ambient conditions would be possible. But due to the very real potential for unmanageable model size, it would only be feasible to provide inputs of pollutants and "outputs" of levels of water quality at a few locations relative to, say, the number of stream and river miles covered. Finally, even in this computer intensive age, it would be expensive to include all the rivers, streams, lakes, estuaries, and bays in the nation, or even all those with significant pollutors, pollution problems, or receiving significant human use. (One such comprehensive model for predicting levels of water quality in the U.S., for example, covers less than 20 percent of the fishable waters in some states and has "nodes" for pollution introduction and water quality prediction, on average, 66 miles apart.)

To assess the usefulness of such models in estimating the benefits associated with improvements in the nation's water quality, four major questions remain to be answered: (1) Are the water quality predictions at preassigned nodal points accurate enough to support the valuation methods used to estimate benefits? (2) Are the predicted levels of water quality at preassigned nodal points sufficiently representative of the water quality at other locations along the same river, lake, or bay? (3) Is the geographic coverage of river systems sufficient to capture the bulk of the benefits? (4) Can usable relationships be developed between the measures of levels of water quality of which the model predicts and the effects on humans and their activities? In other words, are comprehensive national water quality models sufficiently accurate and sufficiently disaggregated to be of use in estimating national totals? Analogous questions may be asked for models of air pollution dispersion, groundwater contamination, or ocean ecosystem response to toxic metals in sludges.

As a general matter, comprehensive natural systems models covering the U.S. will be necessary for national benefits estimation; but such models either do not exist or exist only in very rough form. A useful preliminary exercise would be a state-of-the-art review of those natural systems models potentially usable in national benefits estimation. Such a review should consider explicitly the indicators of ambient environmental conditions and the spatial and temporal resolution of these indicators demanded by the various valuation methods discussed in the first part of this research agenda. Such a review should be undertaken by an interdisciplinary team so that the aim of benefits estimation is not lost sight of in the enthusiastic pursuit of scientific detail. Such a review should precede specific commitments to natural systems modeling projects.

3. High Priority Research Projects

- Developing generally applicable methods for predicting the impact of environmental policy on discharges of pollutants and releases of contaminants

  [For ex ante analysis of a particular pollutant, or class of pollutant, attempt to predict the effects of the environmental policy or regulation on discharges of the pollutant or releases of the contaminant.]

- Developing generally applicable methods for the separation of effects of exogenous factors from effects of environmental policy

  [For ex post analysis of a particular region and a particular pollutant, attempt to separate the effects of changes in environmental policy from changes in exogenous factors that might have affected the levels of the pollutant under consideration.]

- State-of-the-art review of comprehensive, natural systems models potentially useful in national benefits estimation.

  [Review existing natural systems models in relation to the information demands of various benefits valuation methods (discussed in the first part of the agenda) and to the need to produce national totals.]

Improving Estimates of National Benefits

For some of the nation's environmental programs and regulations, estimates of national benefits have already been produced; for others, such estimates have not yet been attempted. For all existing estimates, there remain uncertainties and controversies. These may be serious enough to undermine the usefulness of the estimates in policy decisions. A concerted effort must be made to reduce these uncertainties if benefit estimates are to reach their full potential for informing policy decisions.

As pointed out in section II, and again briefly in this section, the uncertainties in national estimates result from a compounding of uncertainties in the estimates of the four major linkages, from errors associated with overlooking some environmental impacts and double counting others, from errors introduced into the analysis by neglecting simultaneous solution (general equilibrium) problems in situations where adjustments are possible and substitutes are available and where price changes occur, and from errors associated with aggregating benefits across consumers, producers, locations, and benefits categories.

The objective of the research needs addressed here is to learn how to reduce systematically the uncertainties in national estimates, and how to do so at least cost (of research, data collection, and analysis). This entails: first, assessing the level of uncertainty in national estimates; then, determining the sources of this uncertainty; and finally, exploring opportunities for reducing these uncertainties. Due to its enormously broad scope, this problem requires an interdisciplinary approach involving the inputs of economists, natural scientists, engineers, and systems analysts, among others. Such information, assuming it were possible to produce it, would provide an objective basis for ranking future research projects aimed at improving estimates of national benefits.

Research on various "pieces" of the national benefits estimation problem has been supported by the EPA's Office of Research and Development (ORD) for more than a decade. We feel the time has now come for a parallel effort that would attempt to place the individual pieces in perspective. Such an effort would not be fruitful, however, unless it were disciplined by the intent to seek ways of reducing the uncertainty in estimates of national benefits.

At this time, not enough is known about the sources of uncertainty, the quantitative relationships among valuation methods and the other major linkages in benefits estimation, or about the properties of alternative aggregation procedures, to suggest the best approach to reducing the uncertainties in national estimates. This is primarily an empirical issue and will require some "case studies" and experimentation before more informed guidance can be provided. But research on the sources of uncertainties in national estimates, on the relative contributions to these uncertainties, and on opportunities for reducing uncertainties in the most cost-effective manner seems to us to be an effort worthy of the EPA's support. The ultimate goal of such research would be to improve estimates of national totals. A more immediate goal would be to provide objective guidance on research needs and priorities the next time around.

<u>High Priority Research Project</u>

- A pilot project on comprehensive analysis of uncertainties in national benefits estimates

VI. Budget Projections

The costs of the research projects discussed in section V have been estimated, and in this section we summarize the budget implications of embarking on the program outlined in this report. The assumptions and methods on which the cost figures are based are as follows:

- For research projects (those involving methodological development, estimation using existing data sets, or modest survey efforts) we estimated required senior professional person-years and costed these at $150,000 each. The intention was to cover not only the indirect costs of the institutions involved, but also the time of junior research staff, graduate students or research assistants, and other support. This person-year cost should also provide some margin for publication expenses. Computer and survey expenses were added separately based on our experiences with similar projects.
- For the large data gathering projects, we used the following unit costs:

  Recreation surveys: $180 per final personal interview, including survey development, screening Interviews, and data coding. (Based on costs of 1980 U.S. Fish and Wildlife Fishing and Hunting Survey.)

  Health surveys: $700 per person for single cross-section, including sampling, contacts, interview, physical exam, fee, and overhead. $500 per person per year for a continuing panel study.
- For major conferences: $60,000 each
- For committee meetings: $14,000 each

We should stress that these figures are in 1980 dollars and that none of the overall budget implications discussed below have been adjusted for inflation. Further, it should be noted that while our cost estimates include the indirect costs of research institutions, they do _not_ reflect internal EPA costs of program administration. These could be substantial if a large-scale research and data gathering program were launched.

It is our conclusion, on the basis of these assumptions, that all the methodological and estimation research outlined above could be accomplished in roughly 3 years at a total cost of about $8.5 million, or about $2.8 million per year. (It might take a year or more to prepare and launch such an ambitious program. Identifying researchers and institutions, soliciting and reviewing proposals, and clearing contracts or agreements would all require significant time.) Holding one major conference per year on areas of substantial dispute, such as survey techniques for determining willingness to pay, or finding health effects via macro level epidemiology,would add $180,000. Annual meetings of this committee, which we recommend, would add roughly another $40,000. A modest contingency fund of roughly 3 percent of the research budget would bring the total cost of the program to about $9 million over three years.

If resources are available, the vital task of improving available data bases could be undertaken as well. These projects are individually much more expensive than those involving methodological development, the manipulation of existing data, or even modest forays into applications of survey techniques. Indeed, if a decision is made to begin a health-effects panel study, it will be necessary to think in terms well beyond the three year time frame that dominates this report and to be prepared to spend very large sums indeed.

The collection of comprehensive health data on individuals, connected closely to information on personal habits and exposure to environmental and workplace pollution is, in our opinion, the highest priority among the data gathering projects. It can be undertaken at either of two levels. A one-time cross-section study of 10,000 individuals would, we estimate, cost on the order of $7 million. Such a study would require a good deal of planning, sample design, pretesting of questionnaires, respondent contact, and subsequent follow up to obtain exposure levels based on places of residence and work. There would, in addition, be the task of data coding. It is unlikely that all phases could be completed in less than 4 years.

Even more ambitious, but also more valuable in the long run, would be a continuing panel study of several thousand individuals. If 10,000 individuals were involved over 20 years, the total cost in 1980 dollars would, we estimate, be roughly $80 million.

Data on recreational use of water bodies is currently woefully inadequate for national water pollution control benefit estimation. An effort to provide a data base at least as useful for such activities as boating, swimming, picnicking, and hiking as the U.S. Fish and Wildlife quinquennial surveys are for fishing would involve a substantial survey enterprise. Based on Fish and Wildlife Service experience, with a combination of telephone screening and personal interviews, the cost to develop a 10,000 person-sample would be about $1.8 million.

It seems clear that data gathering in the area of materials damage could also have a high payoff and would involve substantial costs. But we do not feel able to provide cost estimates or even a rough description of such an effort. Instead, we confine ourselves to suggesting that, in addition to the pilot methodological project, a set of three or four reconnaissance studies aimed at specific sectors be carried out to provide guidance for future directions. If each such survey involved national sampling and direct surveys of individual household or firm experiences and costs, each could easily cost $250 thousand. The budget implication of this recommendation is therefore a further $1.0 million.

To summarize the discussion, then, we have:

Table 6. Estimated Budgets for Research on Developing National Benefit Estimates of Reduced Pollution

(1980 Dollars)

	With Single Cross-Section Health Effects Data Effort ($ million)		With Continuing Panel Health Effects Data Effort ($ million)
Methodology and Estimation[a]	$ 8.50		$ 8.50
Conferences	.18		.18
Meetings of Committee	.04		.04
Contingencies	.28		.28
Subtotal	9.00		9.00
Health Data	7.00		80.
Recreation Data	1.80		1.80
Materials Data	1.00		1.00
TOTAL (over three years)	$18.80		$91.80
Per Year	$ 6.27	(For First 3 Years)	$ 8.90[c]

[a] Includes pilot project on comprehensive analysis of uncertainties.

[b] $10,000 subjects @ $500 per year over twenty years, with sufficient mortality to reduce undiscounted total costs to $80 mil.

[c] Includes $5 mil. per year for health data study.

APPENDIX A: AD HOC COMMITTEE ON ECONOMICS RESEARCH IN ESTIMATING BENEFITS FROM REDUCED POLLUTION

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*Attended meeting of the Ad Hoc Committee held in Washington D.C., December 29th and 30th, 1980. Other participants at the meeting included, from RFF: Paul R. Portney, Clifford S. Russell, Mark F. Sharefkin, and Walter 0. Spofford, Jr.; from EPA: Alan Carlin, George Provenzano, and John Reuss.

†Commented on draft report.

APPENDIX B: WHAT ARE ECONOMIC BENEFITS?

Introduction

While the preceeding report is intended to be a nontechnical presentation about research on environmental quality benefits, some basic knowledge about a few key concepts for economic theory is essential to understanding both the research approaches taken and the results attained. The most central of these concepts is that of an economic demand for a good (a material object which is valued by people) or service. When economists speak of demand, they are referring to the relationship between the real or hypothetical price of a good or service and the amount of it consumers will wish to buy at that price. Except in very unusual cases, the amount consumers will want to take will be less the higher the price. The discussion here of economic demand is simple and straightforward, but very compact. Close attention on the part of the reader not familiar with these ideas is invited.

Individual Demand

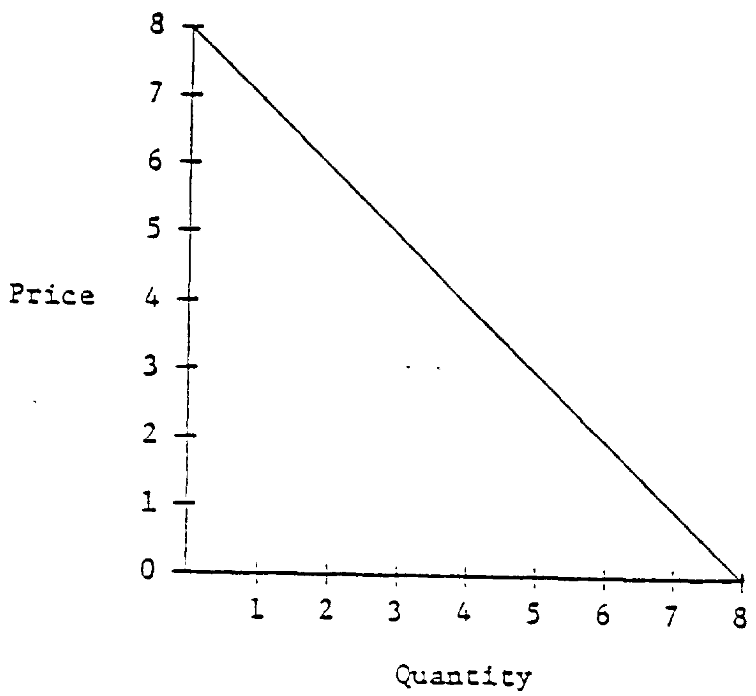
Let us start with a look at individual demand. Consider the following numerical example of an individual's price quantity relationship for the fictitious commodity widgets.

Price of Widgets	Quantity Taken by Consumer	Price Times Quantity	Price Times Incremental Quantity	Accumulated Price Times Incremental Quantity
8	0	$ 0	0	$ 0
7	1	7	7	7
6	2	12	6	13
5	3	15	5	18
4	4	16	4	22
3	5	15	3	25
2	6	12	2	27
1	7	7	1	28
0	8	0	0	28

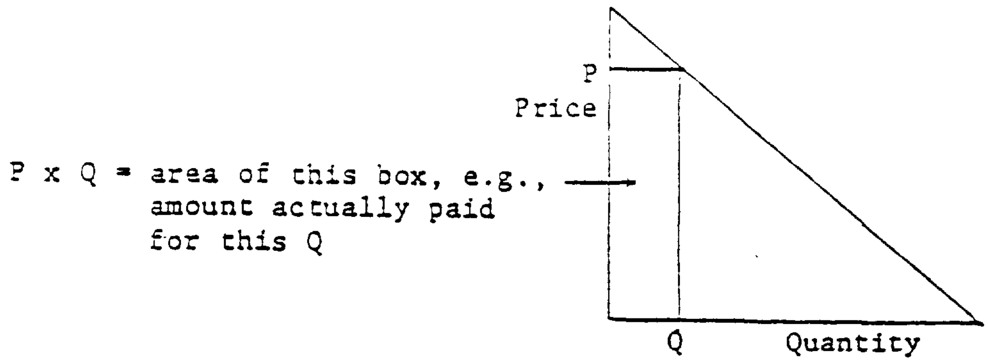
At a price of eight dollars, the consumer will buy no widgets, at six dollars, he will buy two, and so on. If, for whatever number he does wind up buying, he is charged the same amount for each one (this is the usual practice in actually existing markets), then the third column, in which the price is multiplied by the number taken, will indicate how much he _actually_ does pay. But if one could figure out a way to make him pay the maximum he is willing to pay for _each individual_ unit (column four) or be deprived of having any widgets at all, then the accumulated price times incremental quantity shown in the last column would reflect his _total willingness to pay_ for widgets. This is the amount he would pay in an "all or nothing" situation where he either pays everything he would be willing to pay or he is deprived of widgets altogether.

Now suppose that our consumer decides he wishes to buy 5 widgets because the going price for widgets is $3 per item. He then actually pays $15, but if he had had no alternative but to pay the maximum he would have _been willing to pay_, then he would have paid $25 for the three. The difference between what he did pay and what he would have been willing to pay, $10, may be thought to be some extra benefit which the consumer gets because there are such things as widgets available in the market. But because they are uniformly priced at a level less than his maximum willingness to pay, he gets this extra benefit. This additional value is called _consumer's surplus_ by economists. If it were to be the case that the consumer is not required to pay anything for the widgets, he takes eight and his consumer's surplus will be equal to his total willingness to pay--$28. In all cases where there is a positive price, his total willingness to pay will be greater than what he actually does pay because it will include what he actually pays and his consumer's surplus. For example, if he buys four widgets, his willingness to pay equals what he actually does pay plus his consumer's surplus (i.e., \$16 + \$6).

It is usual in expositions of consumer demand theory to express these ideas graphically by plotting a demand curve for the individual. Below is a plot of the numerical example just reviewed.

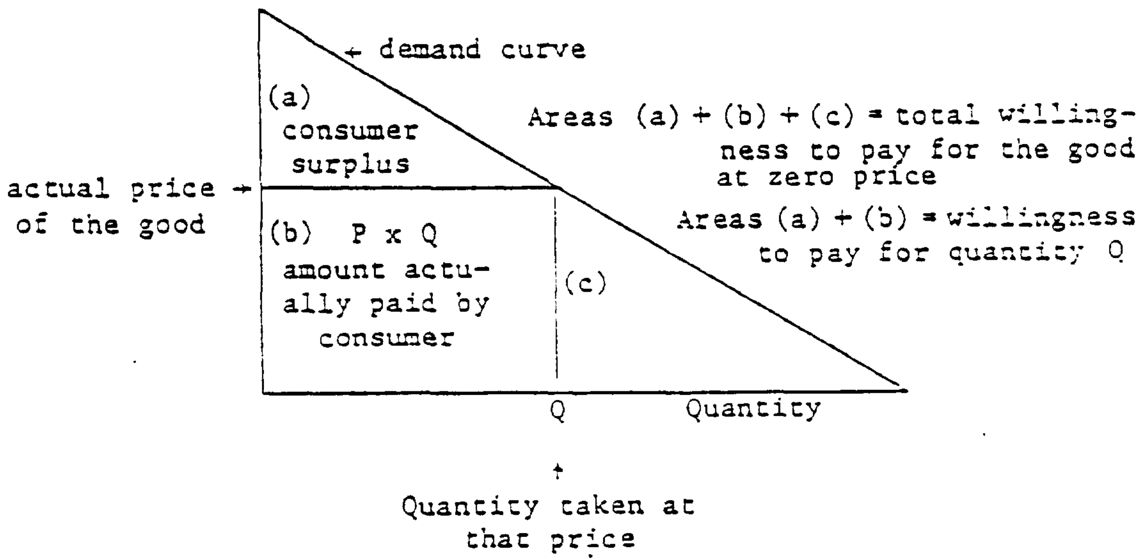


In the simple example, the demand curve is a straight line. This line is generated by plotting a price quantity pair point for each of the pairs shown in the numerical example, with interpolation between the points. It is pretty apparent that the accumulated price times incremental quantity column (willingness to pay) is the accumulated area under the demand curve. To see this, observe that every individual price times quantity pair make a box on the graph as shown more abstractly below.



Since the curve represents every possible combination of such Ps and Qs (all possible boxes), it follows that the area under the whole curve is equal to the consumer's willingness to pay at zero price for Q.

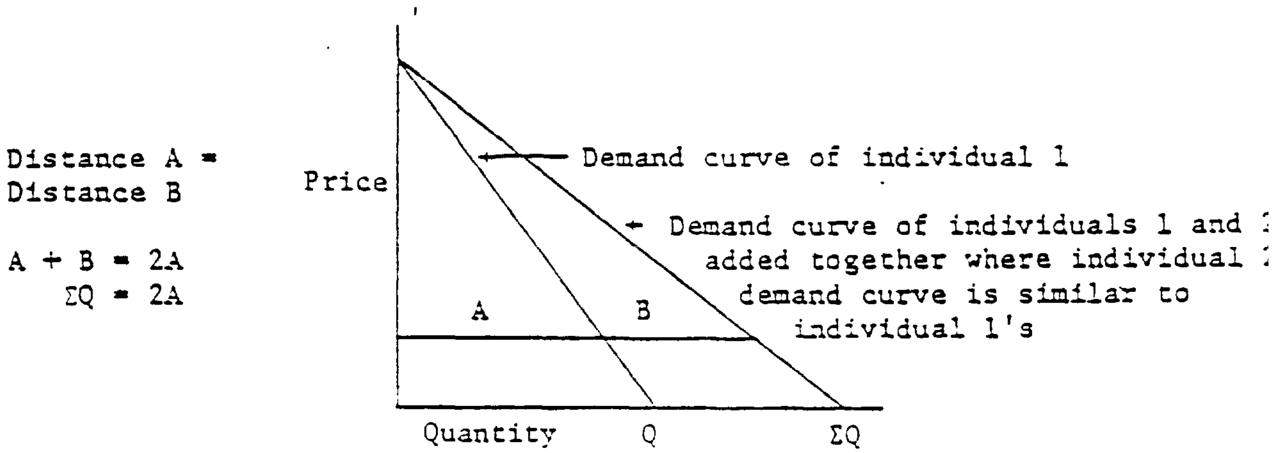
Again, then, more abstractly than in the numerical example above, let us use a graph to review all the main ideas we have defined so far.



Aggregate Demand

So much for the individual consumer. But for many purposes, specifically in the case of environmental goods, one is interested in what is the total demand by all consumers for a good or service (in this case, widgets). How, then, does one add up the demands of all consumers in this market? If one is willing to make the assumption that all persons in the market for widgets should be treated equally, that is, to say everyone's demand counts the same in making up the sum, the answer is very easy--we just add them up. For example, assume that there are two individuals in the widget market and both are just alike--say both are like the one in the numerical example. In this case, the aggregate demand would be just double the individual demand at any given price. For example, at the price of $5, aggregate Q would be 6, P x Q would be $30, and P x Q accumulated would be $36.

Again this adding up process can be illustrated a little more abstractly and generally with a graph.



There is no reason why individuals would need to be similar to make the adding up work. Everything is done the same way if they are not, only the numbers are different. Once an aggregate demand curve has been calculated, the concepts of willingness to pay and consumer's surplus apply to it in the same way as to the individual demand curve (still assuming we are willing to treat everything equally for this purpose).

Stated in its broadest terms, the objective of the research needs described in the foregoing document is to develop methods to derive estimates of the demand (willingness to pay) for improved environmental quality which would then be at least loosely comparable to the demand for other goods and services. This is to permit, at least roughly because of the uncertainties involved, comparison of the value consumers place on better environment relative to other goods and services they buy. In practice, this is a very hard problem. But, unfortunately, even from the standpoint of ideas and concepts, the exposition of basic ideas is not yet complete enough to provide a foundation for quantitative analysis because, in fact, improved environment is not a good similar to widgets. Economists refer to goods like widgets as <u>private goods,</u> and goods like improved environment as <u>public goods</u>.

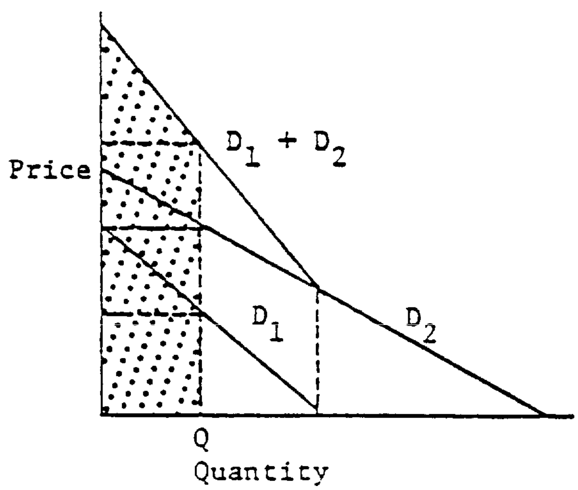
<u>Private Goods and Public Goods</u>

In the economist's lexicon, widgets are private goods because they are divisible and separable. If you buy a widget and use it, that same widget does not at the same time render a service to me. If I buy and eat a banana, you cannot buy and eat that same banana. Such goods are easy for the private sector to produce and market because they come in distinct, divisible units and can be sold to distinct, divisible buyers. Should you, however, go and buy cleaner air in the city where you and I reside, say by paying industries to clean up, the services of that cleaner air are at the same time available to me even though I paid nothing for them. Such goods are called public goods because their units are not divisible and distinct. Their services are available to many persons at the same time, including those who do not pay for them. Private markets are very bad at producing such goods; indeed, there usually is no private economic incentive to produce them at all because while many people could benefit from them, no single individual has a sufficient incentive to pay for them.

Two chief implications for the research reviewed in the preceeding report flow from this situation. First, while in principle it is possible to think of an individual demand curve for cleaner air just like a demand curve for widgets, there usually will not be market price information which will help <u>directly</u> in defining such a curve. Sometimes, however, such information is helpful <u>indirectly</u>. This means further that development of methods for obtaining information on how consumers value, or would value, cleaner air, or other environmental improvements if they had more information, is a very important task. This is the central topic of the preceeding report.

A second implication is that if individual demand curves are available for a public good, they cannot properly be added up in just the same way as for a private good. The way adding up for private goods proceeds is called summing <u>horizontally</u>. This is what was done in the illustration for widgets. Individual demands for public goods must be summed <u>vertically</u>.

To see this, refer back to the widgets example. Assume that instead of demand for widgets, the columns refer to successively lower prices for air quality improvements for an individual consumer and the quantities of improvement the consumer would want at those prices. P x Q and P x Q accumulated have the same interpretation as for private goods for this one individual. But now add a second consumer as was done in the private goods case. With the second consumer added in, it does not mean that more units of cleaner air eill be taken at a given price, as was the case with the private good. The <u>same</u> units of quantity are available to both consumers. Thus, the willingness to pay for up to three units of cleaner air is $18 for the first individual <u>plus</u> $18 for those same three units, or a total of $36. As noted, the kind of summing done here is called <u>vertical</u> summing in contrast to the <u>horizontal</u> summing for private goods. Again, this can be illustrated graphically. It is easier to show the procedure when demand curves for the two individuals are not equal, so the illustration presented assumes they are not. In the graph below, individual demand curves, say for air quality, are designated D_1 and D_2. For any given level of air quality, say Q, the willingness to pay for up to that level (the cross-hatched area) is the willingness to pay of D_1 plus the willingness to pay of D_2 for the same quantity of air quality improvement.



This total willingness to pay for Q units of clean air is in economic terminology the "benefit" of Q units of clean air. Since no price is charged for these Q units of air, it is also the consumer's surplus associated with the provision of Q units of clean air.

Compensation.

A final note on concepts of demand; economic reasoning indicated that when a situation is being considered in which persons are deprived of something they otherwise would have had, as when previously clean air is polluted, willingness to pay for the clean air is not the fundamental test of its value to them. Rather, if they are to be as well off as before the change, one must ask how much they would have had to be compensated to be as well off as before. Generally speaking, willingness to pay is easier (although usually not easy) to estimate than required compensation. If the situation is that the change in economic welfare because of air quality deterioration is rather small relative to overall economic welfare, the willingness to pay measure is about equal to the compensation measure. In most of the studies described in the text of this report, it is presumed that this is the case, and that the emphasis is on willingness to pay.